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Head and Neck

Dr BD Chaurasia (1937–1985)
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member of a number of scientific societies.
He had a large number of research papers to his credit.

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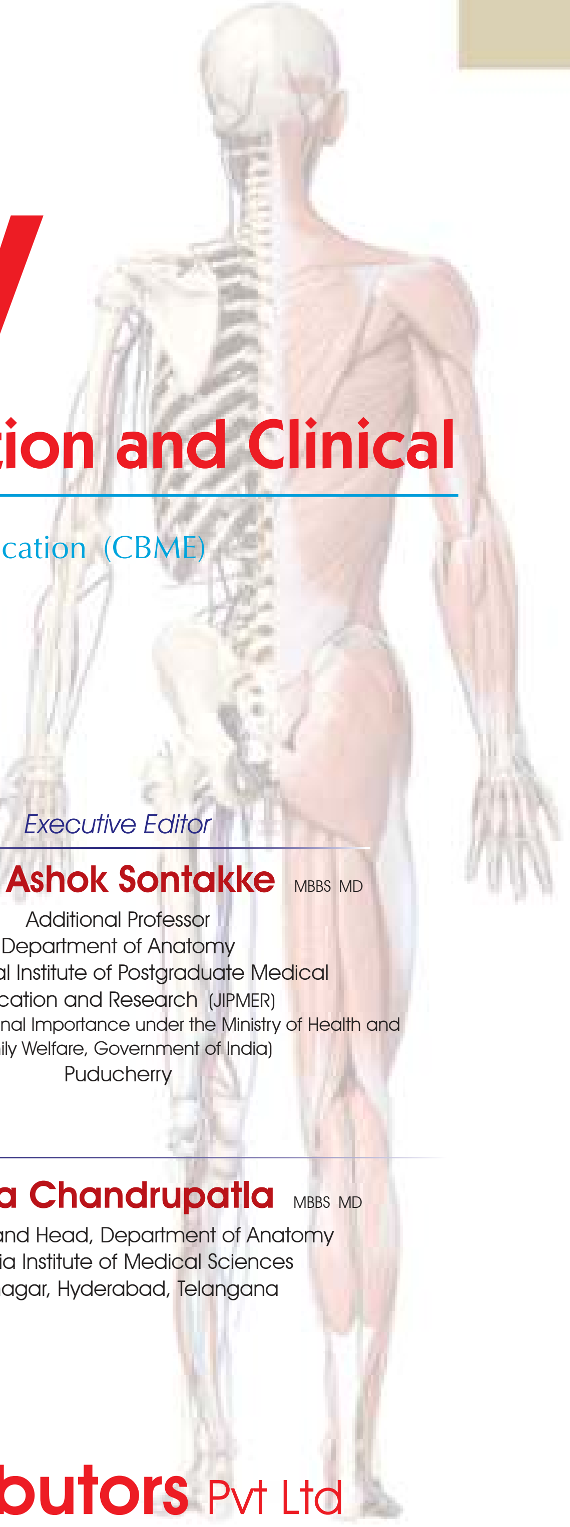

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to

my teacher
Shri Uma Shankar Nagayach

— BD Chaurasia

Volume 1 **UPPER LIMB** and **THORAX**

Volume 2 **LOWER LIMB, ABDOMEN** and **PELVIS**

Volume 3 **HEAD** and **NECK**

Volume 4 **BRAIN–NEUROANATOMY**

Preface to the Tenth Edition

With the change in time, the needs of the students and curriculum are continuously changing. The science is continuously evolving. To integrate the solutions to common problems faced by the students and to follow the latest NMC guidelines for the CBME curriculum, the most widely accepted and read book has been revised thoroughly to maintain the standards of the last half-century. The primary goal of this book is to help the students for easy understanding and rapid grasping of knowledge for their higher academic achievements, to prepare them for all academic formative, summative and entrance examinations and to make it extremely student-friendly.

Anatomy forms the foundation of the clinical knowledge. This book has been made more clinically oriented with the following salient features:

- **Complete** and **time-tested textbook** boasting unparalleled **quality content** designed to enrich both fundamental and clinical understanding for students.
- **Simple text** is the main feature of the book. It will facilitate easier understanding for students. Small sentences minimize effort, enhancing readability and accessibility. This approach ensures clarity of information, aiding students in grasping complex concepts effortlessly.
- **3D colour illustrated plates** will aid the students in comprehending anatomical structures and their relationships with clarity. These visual aids offer a dynamic perspective, enhancing spatial understanding and facilitating the identification of anatomical features.
- **Simple line diagrams** are incorporated. These diagrams will allow students to easily redraw them during examinations. These diagrams are designed for clarity and simplicity, ensuring that students can accurately reproduce anatomical structures in assessments and examinations efficiently.
- **Flowcharts** will facilitate rapid revision and memorizing of facts, alleviating students' concerns about time constraints during the subject review. These visuals will enhance comprehension and retention. Students can quickly navigate through key concepts, optimizing study time and effectively addressing time limitations in their revision process.
- **Clinical anatomy** sections are integrated at the end of each topic to maintain the purpose towards **early clinical exposure** (ECE). By seamlessly merging theoretical knowledge with practical application, this approach ensures students gain valuable insights into clinical contexts, enhancing their understanding and readiness for real-world clinical scenarios.
- **Dissection boxes** will guide the students in the step-wise dissection of the human cadaver.
- **Tables** are used to summarise essential facts for clear understanding and retention.
- *QR codes* for ***eSmartQuiz*** are embedded in the text, which will grant access to online MCQ tests for self-assessment at the end of each chapter. This interactive feature will enhance engagement and facilitate convenient self-evaluation. Students can assess their understanding, reinforce learning, and identify areas for improvement, facilitate a dynamic and effective learning experience.
- ***Free Workbook:*** The main textbook is supported with a workbook, which has the following:
  1. **Clinicoanatomical problems** emphasize early clinical exposure and vertical integration in medical education. By integrating anatomical knowledge with clinical practice from the outset, students gain a holistic understanding of medical concepts. This approach fosters practical skills, enhances diagnostic abilities, and promotes a deeper comprehension of the human body's complexities within clinical contexts.
  2. **Practice figures** aid in preparing students for academic examinations by providing hands-on experience with exam-style preparation. It will help to build confidence in tackling the challenges commonly encountered in academic assessments.
  3. **Multiple choice questions (MCQs)** will serve as potent tools for reinforcing learning, assessing comprehension, and enhancing attention and critical thinking skills. Through MCQs, students engage actively with the curriculum, consolidate understanding, and develop the ability to analyse information critically, ultimately fostering deeper comprehension and retention of knowledge.
  4. **Spotters** and **question bank** introduce students to the examination system by familiarising them with the format and types of questions commonly encountered in assessments. These wide ranges of questions will aid the students in preparing for examinations and gaining confidence in tackling examination challenges effectively.

- ***Free access to BDC's Anatomy eBook (digital content through CBSiCentral app):*** It includes the following:
  a. Additional topics and clinical aspects
  b. *Viva voce* questions, and
  c. Topics for further reference and reading.

  This digital resource will enhance the book's utility, providing students with expanded knowledge and resources for comprehensive learning. Accessible supplementary materials will enhance understanding and facilitate deeper exploration, empowering students to excel in their studies and clinical practice.
- **Free Access to CBSiCentral App:** It includes videos of osteology and soft parts and chapter-wise self-assessment MCQ tests. The videos of the dissection will give three-dimensional image descriptions of tissues and organs, which get effectively registered in the brain for a longer time.
- **Wall charts:** Each volume is provided with meticulously crafted wall charts, elegantly designed and tailored to enhance students' comprehension of anatomy. These visually engaging aids can be easily affixed to walls to grasp the visual impressions of anatomy.

Always remember that success is achieved only through diligent effort and hard work.

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Preface to the First Edition (excerpts)

The necessity of having a simple, systematized and complete book on anatomy has long been felt. The urgency for such a book has become all the more acute due to the shorter time now available for teaching anatomy, and also to the falling standards of English language in the majority of our students in India. The national symposium on 'Anatomy in Medical Education' held at Delhi in 1978 was a call to change the existing system of teaching the unnecessary minute details to the undergraduate students.

This attempt has been made with an object to meet the requirements of a common medical student. The text has been arranged in small classified parts to make it easier for the students to remember and recall it at will. It is adequately illustrated with simple line diagrams which can be reproduced without any difficulty, and which also help in understanding and memorizing the anatomical facts that appear to defy memory of a common student. The monotony of describing the individual muscles separately, one after the other, has been minimised by writing them out in tabular form, which makes the subject interesting for a lasting memory. The relevant radiological and surface anatomy have been treated in separate chapters. A sincere attempt has been made to deal, wherever required, the clinical applications of the subject. The entire approach is such as to attract and inspire the students for a deeper dive in the subject of anatomy.

The book has been intentionally split in three parts for convenience of handling. This also makes a provision for those who cannot afford to have the whole book at a time.

It is quite possible that there are errors of omission and commission in this mostly single-handed attempt. I would be grateful to the readers for their suggestions to improve the book from all angles.

I am very grateful to my teachers and the authors of numerous publications, whose knowledge has been freely utilised in the preparation of this book. I am equally grateful to my professor and colleagues for their encouragement and valuable help. My special thanks are due to my students who made me feel their difficulties, which was a great incentive for writing this book. I have derived maximum inspiration from Prof. Inderbir Singh (Rohtak), and learned the decency of work from Shri SC Gupta (Jiwaji University, Gwalior).

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Videos of bones and soft parts of human body, prepared at Kathmandu University School of Medical Sciences, have now been added with the respective chapters and are available at our mobile App CBSiCentral. We are grateful to Dr R Koju, CEO of Kathmandu University School of Medical Sciences (KUSMS) and Dhulikhel Hospital, for his generosity.

The moral support of my (chief editor) family members, Late Dr DP Garg, Dr Suvira Gupta, Dr JP Gupta, Mr Manoj, Ms Rekha, Mr Sanjay, Ms Meenakshi, Dr Manish, Dr Shilpa Garg, Dr Naveen Garg, Dr Manoj, Dr Nalini Shukla, Dr Vikas Verma and Dr Swati Gupta, is appreciated.

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- Dr Mamta Kumari (Pawapuri, Bihar)
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- Dr Pankaj Singh (Jaipur, Rajasthan)
- Dr Pankaj Soni (Mandi, HP)
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- Dr Prajakta Kishve (Hyderabad, Telangana)
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- Dr Prashant E Natekar (Hyderabad)
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- Dr Prathistha Potdar (Greater Noida, UP)
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- Dr Pratima Jaiswal (Kota, Rajasthan)
- Dr Praveen B Iyer (Mumbai, Maharashtra)
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- Dr Pritha S Bhuiyan (Mumbai, Maharashtra)
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- Dr Priti Sinha (Meerut, UP)
- Dr Priya P Roy (Karad, Maharashtra)
- Dr Priya Ranganath (Bengaluru, Karnataka)
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- Dr Punita (Lucknow, UP)
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- Dr Purushotam Rao (Vikarabad, Telangana)
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- Dr R Azhagiri (Chennai, TN)
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- Dr Rachna Magotra (Jammu)
- Dr Rachna Rastogi (Greater Noida, UP)
- Dr Rajan Singla (Patiala, Punjab)
- Dr Rajashree Biswal (Cuttack, Odisha)
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- Dr Rajat Subhra Das (Raebareli, UP)
- Dr Rajeev Panwar (KK Nagar, Chennai, TN)
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eSmartQuiz – Online MCQ Test

After attending the class, students should go through the "*eSmartQuiz* – Online MCQ test" for the following reasons:

- *Reinforcement of Learning*: The "*eSmartQuiz* – Online MCQ test" provide an opportunity to reinforce learning after attending a class or reading a book. It helps to assess understanding and retention of concepts, to solidify knowledge and identify areas that need further revision or clarification.
- *Assessment of Comprehension*: The "*eSmartQuiz* – Online MCQ test" is an effective tool to assess comprehension of the subject matter and to demonstrate the ability to apply the concepts learned in the class.
- *Enhancement of Attention and Critical Thinking*: The "*eSmartQuiz* – Online MCQ test" will help to make students attentive for the class and to enhance critical thinking skills by selecting the most appropriate answer among the given options.

Each *eSmartQuiz* test consists of 10 MCQs, mostly image-based, and the students can see their scores at the end of each test. These questions will be modified after a certain interval. Use the given links or scan the QR code (given in each chapter) for the test. One student can solve each test only one time.

Chapter	*Link for* ***eSmartQuiz***
Head and Neck	
1. Osteology of Head and Neck	https://forms.gle/L23dCS6nuUdcH4416
2. Scalp, Temple and Face	https://forms.gle/JCQ9kMV1n5q3hwHd6
3. Side of the Neck	https://forms.gle/o7xkkfE8nZwp7qUC6
4. Anterior Region of the Neck	https://forms.gle/VzXQVfSfbTaHJZTn7
5. Parotid Region	https://forms.gle/uKsU6corLTTnBovz5
6. Temporal and Infratemporal Regions	https://forms.gle/iP5JkDtKtrRL8r1r8
7. Submandibular Region	https://forms.gle/3NVu6uePp3ZgbUv57
8. Structures in the Neck	https://forms.gle/rukg8W5wummqvsnv9
9. Prevertebral and Paravertebral Regions	https://forms.gle/gVEpDdaTY7kvFWJ99
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12. Cranial Cavity	https://forms.gle/bwgzsWSvQ9HV6KSz9
13. Contents of the Orbit	https://forms.gle/1KgWiySrEVWFhRCUA
14. Mouth and Pharynx	https://forms.gle/F74Vwpj43aHSBxr86
15. Nose, Paranasal Sinuses and Pterygopalatine Fossa	https://forms.gle/tMAGush9LAF929FF8
16. Larynx	https://forms.gle/VyjBKNLUNb4FzEvdA
17. Tongue	https://forms.gle/cT17eXaE9fo1HYKNA
18. Ear	https://forms.gle/618J9JzvQC4Sm9229
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20. Surface Marking and Radiological Anatomy	https://forms.gle/MEpq8w8CXdjvgRyS8

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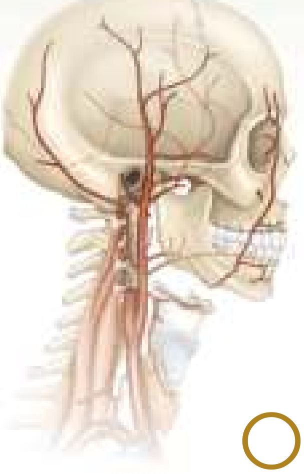


Chapter

1

Osteology of Head and Neck

The *head* is the globular uppermost part of the body, which is connected with the trunk by the *neck*. The *face* is the anterior aspect of head and the muscles present here express facial movements. The *scalp* overlies the lateral, posterior and superior aspects of skull.

Functions of Head and Neck

The head and neck region performs the following functions:

1. Protection to brain, endocrine glands and special senses.
2. Gives passage to food and air and connects their upper parts to their respective lower parts.
3. Produces voice for communication.

Peculiar Features of Human Head and Neck

1. The head comprises skull and lodges the brain covered by meninges, hypophysis cerebri, special senses, teeth and blood vessels. Brain is the highest seat of intelligence.
2. To accommodate the increased volume of nervous tissue, the cranial cavity had to enlarge.
3. Correspondingly, the lower jaw or mandible had to retract.
4. The eyes also had come more anteriorly, on each side of the nose.
5. The external nose also became prominent.
6. The external ear becomes vestigial and chin is pushed forwards to accommodate the broad tongue.
7. Tongue, the organ for speech, is securely placed in the oral cavity for articulation of words, i.e. speech.
8. The vocalisation centre is big to articulate various words and speak distinctly. Speech is a special and chief characteristic of the human.

Regions of Head and Neck

For study purposes, the head and neck are divided into the following regions:

1. ***Frontal region:*** Lies in front of skull.
2. ***Parietal region:*** Lies on top of skull, formed chiefly by the parietal bones. It is seen from the top.
3. ***Occipital region:*** Forms back of skull.
4. ***Temporal region:*** It is the area above the ears.
5. ***Ocular region:*** It is the region around the large orbital openings, containing the precious eyeball, muscles to move the eyeball, nerves and blood vessels to supply these muscles.
6. ***Auricular region:*** The region of the external ear with external auditory meatus comprises the auricular region.
7. ***Nasal region:*** The region of the external nose, its muscles and the associated cavity comprise the nasal region. Sense of smell is perceived from this region.
8. ***Oral region:*** Comprises upper and lower lips and the angle of the mouth, where the lips join each side. Numerous muscles are present here, to express feelings and emotions. These are parts of the muscles of facial expression. They show feelings, without words.
9. ***Oral cavity:*** It houses the organ of speech and taste. Tongue itself is not swallowed, though everything put on the tongue passes downwards.
10. ***Parotid region:*** Lies on the side of the face. It contains the biggest serous parotid salivary gland, which lies around the external auditory meatus.
11. ***Neck:*** Each half of the neck comprises two triangles between anterior median line and posterior median line.
    a. ***Posterior triangle:*** Lies between sternocleidomastoid, the *neck and chin turning muscle*; trapezius, *the shrugging muscle* and middle one-third of the clavicle. It contains spinal root of accessory nerve, proximal parts of the important brachial plexus, subclavian vessels with its branches and tributaries. Its apex is above and base is below.
    b. ***Anterior triangle:*** Lies between the anterior median line and the anterior border of sternocleidomastoid muscle. Its apex is in lower part of neck, close to sternum and base above. It contains the common carotid artery and branches of external carotid artery, last four cranial nerves, lymph nodes.

***Competency*:**
AN26.1 Demonstrate anatomical position of skull, identify and locate individual skull bones in skull.

Bones of Head and Neck

The bones of head and neck include:

1. Skull, i.e. cranium with mandible
2. Seven cervical vertebrae
3. Hyoid
4. Six ossicles of the ear.

SKULL

The skeleton of the head is called the *skull*. It consists of several bones that are joined together to form the ***cranium***. The term skull also includes the mandible or lower jaw, which is a separate bone. However, the two terms, skull and cranium, are often used synonymously (Plate 1.1).

Parts of Skull

The skull can be divided into two main parts:

1. ***Calvaria*** or *brain box*/*neurocranium* is the upper part of the cranium, which encloses the brain. It consists of a skull cap/vault (intramembranous ossification) and a base (intracartilaginous ossification).
2. ***Facial skeleton***/viscerocranium constitutes the rest of the skull and includes the mandible.

Bones of the Skull

The skull consists of 28 bones, including 6 ear ossicles.

1. **Calvaria** or brain box is composed of 14 bones, including three paired ear ossicles.

Paired	*Unpaired*
1. Parietal	1. Frontal
2. Temporal	2. Occipital
3. Malleus	3. Sphenoid
4. Incus	4. Ethmoid
5. Stapes	

2. ***Facial skeleton*** is composed of 14 bones.

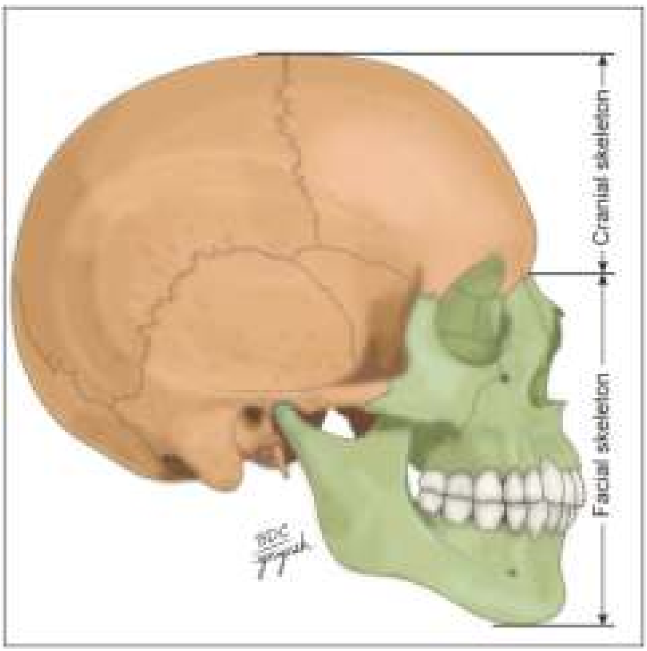
Paired	*Unpaired*
1. Maxilla	1. Mandible
2. Zygomatic	2. Vomer
3. Nasal	
4. Lacrimal	
5. Palatine	
6. Inferior nasal concha	

Skull Joints

The joints in the skull are mostly ***sutures***, a few primary cartilaginous joints and three pairs of synovial joints. The sutures can be classified into:

1. Plane suture — edges of bone are flat, e.g. internasal suture.
2. Serrate suture, e.g. coronal suture.
3. Denticulate suture, e.g. lambdoid suture.
4. Squamous suture, e.g. parietotemporal suture.
5. Schindylesis, e.g. palatomaxillary suture.

Plate 1.1: Cranial and facial skeleton



Movable joints of skull: Two pairs of synovial joints are present between the ossicles of middle ear. One pair is the largest *temporomandibular joint*.

Anatomical Position of Skull

Hold the skull in both the hands so that (Fig. 1.1):

1. The orbital cavities are directed forwards
2. The lower margin of the orbit and upper margin of the external acoustic meatus lie in the same horizontal plane (called ***Frankfurt's plane***).

Note: ***Reid's base line*** is a horizontal line obtained by joining the infraorbital margin to the centre of external acoustic meatus, i.e. auricular point (Fig. 1.1). It is used in conventional radiography when performing CT imaging.

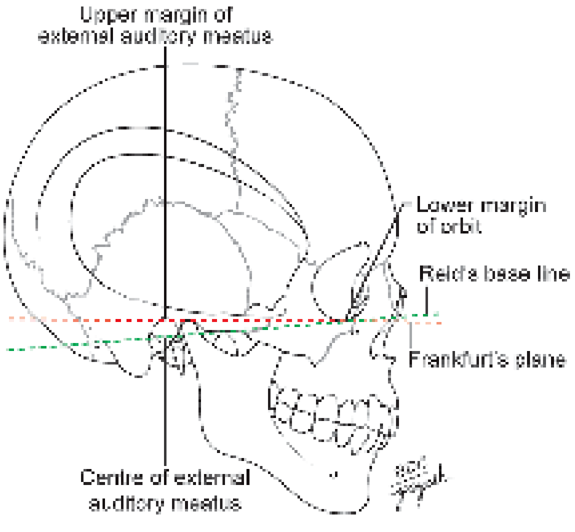

Upper margin of external auditory meatus
Lower margin of orbit
Reid's base line
Frankfurt's plane
Centre of external auditory meatus

Fig. 1.1: Anatomical position of skull

Methods of Study of the Skull

The skull can be studied as a whole. The whole skull can be studied from the outside or externally in different views:

1. Superior view — norma verticalis
2. Posterior view — norma occipitalis
3. Anterior view — norma frontalis
4. Lateral view — norma lateralis
5. Inferior view — norma basalis.

The whole skull can be studied from the inside or internally after removing the roof of the calvaria or skull cap:

   a. Internal surface of the ***cranial vault***.
   b. Internal surface of the ***cranial base*** that shows a natural subdivision into anterior, middle and posterior cranial fossae.

Competency:
AN27.2 Describe emissary veins with its role in spread of infection from extracranial route to intracranial venous sinuses

Peculiarities of Skull Bones

1. Base of skull ossifies in cartilage, while the skull cap ossifies in membrane.
2. At birth, skull comprises one table only. By 4 years or so, two tables are formed. Between the two tables, there are *diploes* (Greek *double*), i.e. spaces containing red bone marrow forming RBCs, granular series of WBCs and platelets. Four diploic veins on each side drain the formed blood cells into neighbouring veins.
3. At birth, the 4 angles of parietal bone have membranous gaps or fontanelles. These allow overlapping of bones during vaginal delivery, if required. These also allow skull bones to increase in size after birth, for housing the delicate brain.
4. Some skull bones have air cells in them and are called pneumatic bones, e.g. frontal and maxilla.
   a. They reduce the weight of skull.
   b. They maintain humidity of inspired air.
   c. They give resonance to voice.
   d. These may get infected resulting in sinusitis.
5. Skull bones are united mostly by sutures.
6. Skull has foramina for 'emissary veins', which connect intracranial venous sinuses with extracranial veins. These try to relieve raised intracranial pressure. Infection may reach through the emissary veins into cranial venous sinuses as these veins are valveless (Table 1.1).
7. Petrous temporal is the densest bone of the body. It lodges internal ear, middle ear, including three ossicles, i.e. malleus, incus and stapes. Ossicles are 'bones within the bone' and are fully formed at birth.
8. Skull lodges brain, meninges, CSF, glands like hypophysis cerebri and pineal, venous sinuses, teeth, special senses like retina of eyeball, taste buds of tongue, olfactory epithelium, cochlear and vestibular nerve endings.

Competency:
AN26.2 Describe the features of norma frontalis, verticalis, occipitalis, lateralis and basalis.

EXTERIOR OF THE SKULL

NORMA VERTICALIS

Shape

When viewed from above, the skull is usually oval in shape. It is wider posteriorly than anteriorly. The shape may be more nearly circular (Fig. 1.2, Flowchart 1.1).

Bones

1. Frontal bone anteriorly.
2. Occipital bone posteriorly.
3. Parietal bone on each side.

Sutures

1. ***Coronal suture*** is placed between the frontal and the two parietal bones. The suture crosses the cranial vault from side-to-side (Fig. 1.2).
2. ***Sagittal suture*** is placed in the median plane between the two parietal bones.
3. ***Lambdoid suture*** lies posteriorly between the occipital and the two parietal bones. It is labda-shaped, hence the name.

Note: ***Metopic*** (Latin *forehead)* ***suture*** is occasionally present in about 3% to 8% of individuals. It lies in the median plane and separates the two halves of the frontal bone. Normally, it fuses at 6 years of age.

TABLE 1.1: The emissary veins of the skull

Name	*Foramen of skull*	*Veins outside skull*	*Venous sinus*
1. Parietal emissary vein	Parietal foramen	Veins of scalp	Superior sagittal sinus
2. Mastoid emissary vein	Mastoid foramen	Veins of scalp	Sigmoid sinus
3. Emissary vein	Hypoglossal canal	Internal jugular vein	Sigmoid sinus
4. Condylar emissary vein	Posterior condylar foramen	Suboccipital venous plexus	Sigmoid sinus
5. 2–3 emissary veins	Foramen lacerum	Pharyngeal venous plexus	Cavernous sinus
6. Emissary vein	Foramen ovale	Pterygoid venous plexus	Cavernous sinus
7. Emissary vein	Foramen caecum	Veins from upper part of nose	Superior sagittal sinus

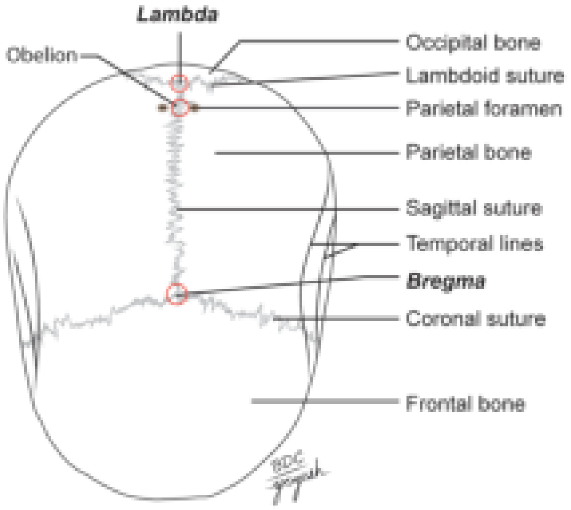
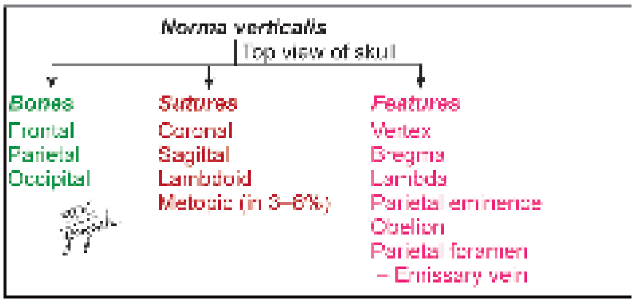

Lambda
Obelion
Occipital bone
Lambdoid suture
Parietal foramen
Parietal bone
Sagittal suture
Temporal lines
Bregma
Coronal suture
Frontal bone

Fig. 1.2: Norma verticalis

Flowchart 1.1: Features of norma verticalis


Norma verticalis
Top view of skull
Bones
Frontal
Parietal
Occipital
Sutures
Coronal
Sagittal
Lambdoid
Metopic (in 3–8%)
Features
Vertex
Bregma
Lambda
Parietal eminence
Obelion
Parietal foramen
– Emissary vein

Features (Fig. 1.2)

1. ***Vertex*** is the highest point on sagittal suture.
2. ***Vault*** of skull is the arched roof for the dome of skull.
3. ***Bregma*** is the meeting point between the coronal and sagittal sutures. In the foetal skull, this is the site of a membranous gap, called the *anterior fontanelle*, which closes at 18 to 24 months of age. It allows growth of brain.
4. ***Lambda*** is the meeting point between the sagittal and lambdoid sutures. In the foetal skull, this is the site of the *posterior fontanelle*, which closes at birth—2 to 3 months of age.
5. ***Parietal tuber*** *(eminence)* is the area of maximum convexity of the parietal bone. This is a common site of fracture of the skull.
6. ***Parietal foramen***, one on each side, pierces the parietal bone near its upper border, 2.5 to 4 cm in front of the lambda. The parietal foramen transmits an emissary vein from the veins of scalp to superior sagittal sinus.
7. ***Obelion*** is the point on the sagittal suture between the two parietal foramina.
8. ***Temporal lines*** begin at the zygomatic process of the frontal bone, arch backwards and upwards and cross the frontal bone, the coronal suture and the parietal bone. Over the parietal bone, there are two lines—superior and inferior. Traced anteriorly, they fuse to form a single line. Traced posteriorly, the superior line fades out over the posterior part of the parietal bone, but the inferior temporal line continues downwards and forwards with zygomatic arch.
9. A pair of anterolateral/sphenoidal fontanelle and a pair of posterolateral or mastoid fontanelles are also present. These fontanelles close within 3–4 months after birth.

NORMA OCCIPITALIS

Norma occipitalis is convex upwards and on each side and is flattened below (Fig. 1.3, Flowchart 1.2).

Bones

1. Parietal bones above.
2. Squamous part of the occipital bone below.
3. Mastoid part of the temporal bone on each side.

Sutures

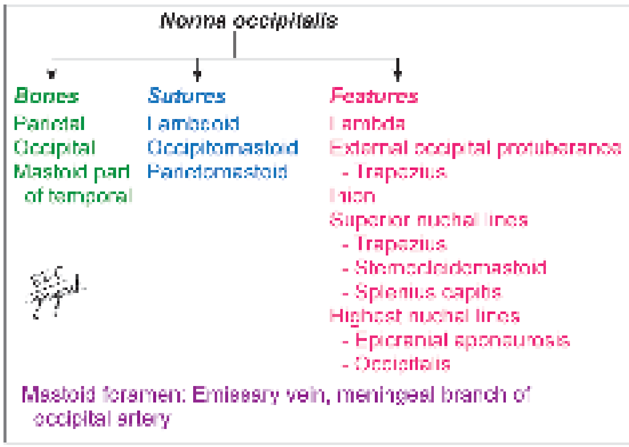
1. ***Lambdoid suture*** lies between the occipital bone and the two parietal bones. Sutural or wormian bones are common along this suture.
2. ***Occipitomastoid suture*** lies between the occipital bone and mastoid part of the temporal bone.
3. ***Parietomastoid suture*** lies between the parietal bone and mastoid part of the temporal bone.

   The posterior part of the ***sagittal suture*** is also seen.

Features

1. *Lambda, parietal foramina* and *obelion* have been examined in the norma verticalis.
2. ***External occipital protuberance*** is a median prominence in the lower part of this norma. It marks the junction of the head and the neck. The most prominent point on this protuberance is called the *inion*.
3. ***Superior nuchal lines*** are curved bony ridges passing laterally from the protuberance. These also mark the junction of the head and the neck. The area below the superior nuchal lines will be studied with the norma basalis.
4. ***Highest nuchal lines*** are not always present. They are curved bony ridges situated about 1 cm above the superior nuchal lines. They begin from the upper part of the external occipital protuberance and are more arched than the superior nuchal lines.

Flowchart 1.2: Features of norma occipitalis


Norma occipitalis
Bones
Parietal
Occipital
Mastoid part of temporal
Sutures
Lambdoid
Occipitomastoid
Parietomastoid
Features
Lambda
External occipital protuberance
- Trapezius
Inion
Superior nuchal lines
- Trapezius
- Sternocleidomastoid
- Splenius capitis
Highest nuchal lines
- Epicranial aponeurosis
- Occipitalis
Mastoid foramen: Emissary vein, meningeal branch of occipital artery

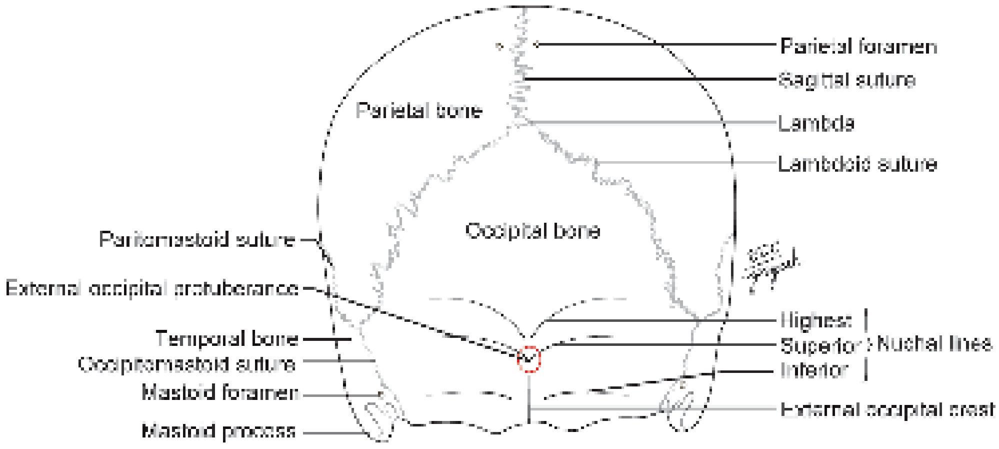

Parietal foramen
Sagittal suture
Lambda
Lambdoid suture
Parietal bone
Occipital bone
Parietomastoid suture
External occipital protuberance
Temporal bone
Occipitomastoid suture
Mastoid foramen
Mastoid process
Highest
Superior
Inferior
Nuchal lines
External occipital crest

Fig. 1.3: Norma occipitalis

5. ***Occipital point*** is a median point, a little above the inion. It is the point farthest from the glabella.
6. ***Mastoid*** (Greek *breast*) ***foramen*** is located on the mastoid part of the temporal bone at or near the occipitomastoid suture. Internally, it opens at the sigmoid sulcus. The mastoid foramen transmits an emissary vein (Table 1.1) and the meningeal branch of the occipital artery.

Note: ***Interparietal bone*** (inca bone) is occasionally present. It is a large triangular bone located at the apex of the squamous occipital. This is not a sutural or accessory bone but represents the membranous part of the occipital bone which has failed to fuse with the rest of the bone.

Attachments

1. The upper part of the external occipital protuberance gives origin to the trapezius, and the lower part gives attachment to the upper end of the ligamentum nuchae.
2. The medial 1/3rd of the superior nuchal line gives origin to the trapezius, and the lateral part provides insertion to the sternocleidomastoid above and to the splenius capitis below.
3. The highest nuchal lines, if present, provide attachment to the epicranial aponeurosis medially, and give origin to the occipitalis or occipital belly of occipitofrontalis muscle laterally. In case of absence of highest nuchal lines, these structures are attached to superior nuchal lines.

NORMA FRONTALIS

The norma frontalis is roughly oval in outline, being wider above than below (Plate 1.2, Fig. 1.4, Flowchart 1.3).

Bones

1. *Frontal* bone forms the forehead. Its upper part is smooth and convex, but the lower part is irregular and is interrupted by the orbits and by the anterior bony aperture of nose.
2. Right and left *maxillae* form the upper jaw.
3. Right and left *nasal* bones form the bridge of the nose.
4. *Zygomatic* (Greek *yoke*) bones form the bony prominence of the superolateral part of the cheeks.
5. *Mandible* forms the lower jaw.

Descriptive Subdivisions

The *norma frontalis* can be studied under the following heads.

1. Frontal region
2. Orbital openings
3. Anterior nasal aperture
4. Lower part of the face.

Frontal Region

The frontal region presents the following features:

1. ***Superciliary arch*** is a rounded, curved elevation situated just above the medial part of each orbit. It overlies the frontal sinus and is better marked in males than in females.

Flowchart 1.3: Features of norma frontalis

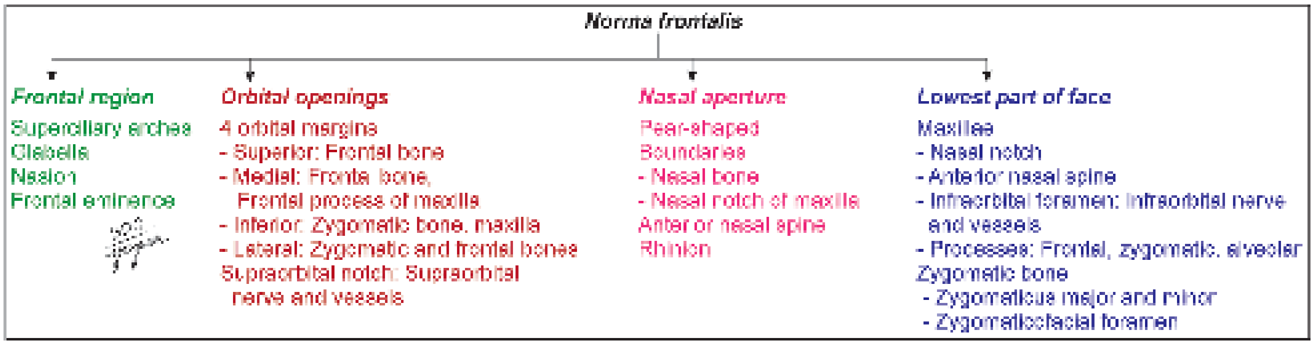
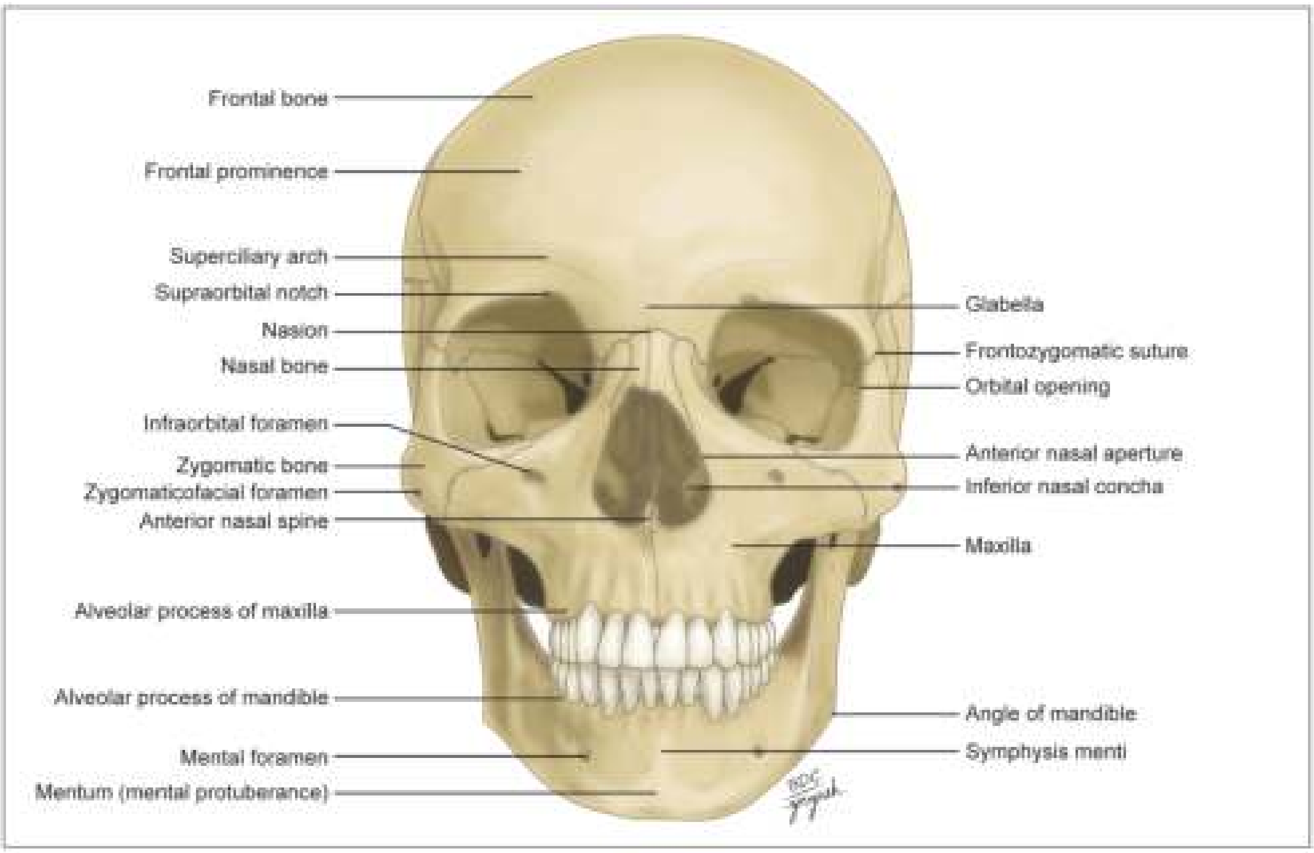

Norma frontalis
Frontal region
Superciliary arches
Glabella
Nasion
Frontal eminence
Orbital openings
4 orbital margins
- Superior: Frontal bone
- Medial: Frontal bone, Frontal process of maxilla
- Inferior: Zygomatic bone, maxilla
- Lateral: Zygomatic and frontal bones
Supraorbital notch: Supraorbital nerve and vessels
Nasal aperture
Pear-shaped
Boundaries
- Nasal bone
- Nasal notch of maxilla
Anterior nasal spine
Rhinion
Lowest part of face
Maxillae
- Nasal notch
- Anterior nasal spine
- Infraorbital foramen: Infraorbital nerve and vessels
- Processes: Frontal, zygomatic, alveolar
Zygomatic bone
- Zygomaticus major and minor
- Zygomaticofacial foramen

Plate 1.2: Norma frontalis


Frontal bone
Frontal prominence
Superciliary arch
Supraorbital notch
Nasion
Nasal bone
Infraorbital foramen
Zygomatic bone
Zygomaticofacial foramen
Anterior nasal spine
Alveolar process of maxilla
Alveolar process of mandible
Mental foramen
Mentum (mental protuberance)
Glabella
Frontozygomatic suture
Orbital opening
Anterior nasal aperture
Inferior nasal concha
Maxilla
Angle of mandible
Symphysis menti

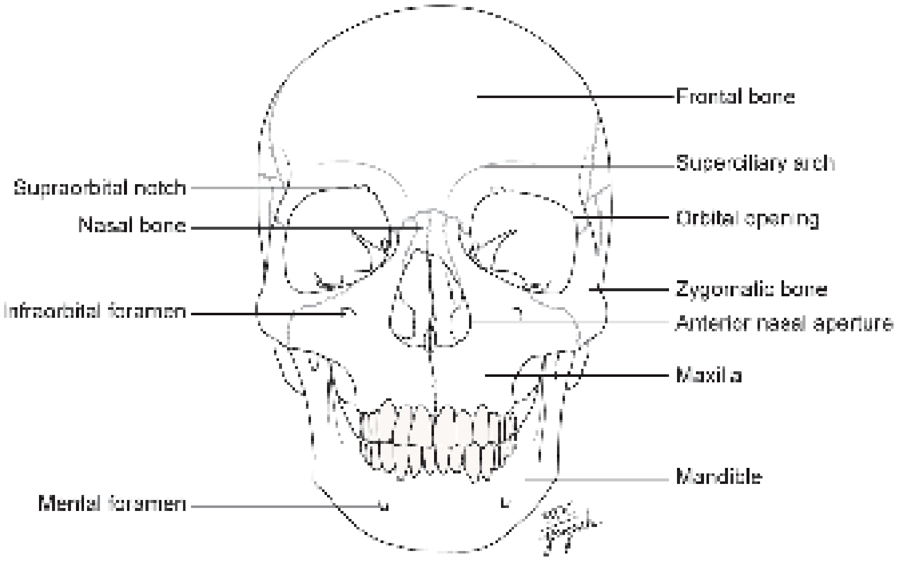

Frontal bone
Superciliary arch
Supraorbital notch
Orbital opening
Nasal bone
Zygomatic bone
Infraorbital foramen
Anterior nasal aperture
Maxilla
Mandible
Mental foramen

Fig. 1.4: Norma frontalis: Walls of orbit, nasal aperture and lower part of face

2. ***Glabella*** is a median elevation connecting the two superciliary arches. Below the glabella, the skull recedes to frontonasal suture at root of the nose.
3. ***Nasion*** is a median point at the root of the nose where the internasal suture meets with the frontonasal suture.
4. ***Frontal tuber*** or *eminence* is a low rounded elevation above the superciliary arch – one on each side. It is more prominent in females and in children.

Orbital Openings

Each orbital (Latin *circle*) opening is quadrangular in shape and is bounded by the following four margins.

1. ***Supraorbital margin*** is formed by the frontal bone. At the junction of its lateral 2/3rd and its medial 1/3rd, it presents the supraorbital notch or foramen.
2. ***Infraorbital margin*** is formed by the zygomatic bone laterally, and maxilla medially.

3. ***Medial orbital margin*** is ill-defined. It is formed by the frontal bone above, and by the lacrimal crest of the frontal process of the maxilla below.
4. ***Lateral orbital margin*** is formed mostly by the frontal process of zygomatic bone but is completed above by the zygomatic process of frontal bone. *Frontozygomatic suture* lies at their union.

Anterior Nasal Aperture

The anterior bony aperture of the nose is pear-shaped, being wide below and narrow above.

Boundaries

Above: By the lower border of the nasal bones.

Below: By the nasal notch of the body of maxilla on each side.

Features

1. *Articulations of the nasal bone:*
   Anteriorly — with the opposite bone at the internasal suture.
   Posteriorly — with the frontal process of the maxilla.
   Superiorly — with the frontal bone at the frontonasal suture.
   Inferiorly — the upper nasal cartilage is attached to it.
2. ***Anterior nasal spine*** is a sharp projection in the median plane in the lower boundary of the piriform aperture.
3. ***Rhinion*** is the lowermost point of the internasal suture.

Lower Part of the Face

The lower part of the face is formed by the following bones:
1. Maxilla forms upper jaw.
2. Zygomatic bone forms malar prominences.
3. Mandible forms lower jaw.

Maxilla

Maxilla contributes a large share in the formation of the facial skeleton. The anterior surface of the body of the maxilla presents:
1. N*asal notch* medially
2. *Anterior nasal spine*
3. ***Infraorbital foramen***, 1 cm below the infraorbital margin
4. ***Incisive fossa*** above the incisor teeth
5. ***Canine fossa*** lateral to the canine eminence.

In addition, three out of four ***processes of the maxilla*** are also seen in this norma.
1. ***Frontal process*** *of the maxilla* is directed upwards. It articulates anteriorly with the nasal bone, posteriorly with the lacrimal bone and superiorly with the frontal bone (Fig. 1.7).
2. ***Zygomatic process*** *of the maxilla* is short but stout and articulates with the zygomatic bone.
3. ***Alveolar process*** *of the maxilla* bears sockets for the upper teeth.

Zygomatic Bone *(Malar Bone)*

1. Zygomatic bone forms the prominence of the cheek.
2. ***Zygomaticofacial foramen*** is seen on its surface.

Mandible *(Lower Jaw Bone)*

Mandible (Latin *to chew*) forms the lower jaw. Its following features are seen in norma frontalis:
1. *Upper border* or *alveolar arch* lodges the lower teeth.
2. *Lower border* or *base* is rounded.
3. Middle point of the base is called the *mental point or* ***gnathion***.
4. The point on the angle of mandible is called ***gonion***.
5. A*nterior surface* of the body of the mandible presents:
   a. *Symphysis menti*, the *mental protuberance* and the *mental tubercles*, anteriorly.
   b. ***Mental foramen*** below the interval between the two premolar teeth, transmitting the *mental nerve and vessels*.
   c. ***Oblique line*** runs upwards and backwards from the mental tubercle to the anterior border of the *ramus* (Latin branch) of the mandible.

Sutures of the Norma Frontalis

1. Internasal
2. Frontonasal
3. Nasomaxillary
4. Lacrimomaxillary
5. Frontomaxillary
6. Intermaxillary
7. Zygomaticomaxillary
8. Zygomaticofrontal.

Attachments

1. The medial part of the superciliary arch gives origin to the corrugator supercilii muscle (Fig. 1.5).
2. Procerus muscle arises from the nasal bone near the median plane.
3. The orbital part of the orbicularis oculi arises from the frontal process of the maxilla and from the nasal part of the frontal bone.
4. Medial palpebral ligament is attached to the frontal process of the maxilla between the frontal and maxillary origins of the orbicularis oculi.
5. Levator labii superioris alaeque nasi arises from the frontal process of the maxilla in front of the orbicularis oculi.
6. Levator labii superioris arises from the maxilla between the infraorbital margin and the infraorbital foramen.
7. Levator anguli oris arises from the canine fossa.
8. Nasalis and the depressor septi arise from the surface of the maxilla bordering the nasal notch.
9. Incisivus labii superioris muscle arises from an area just below the depressor septi. It forms part of orbicularis oris.
10. Zygomaticus major and minor arise from the surface of the zygomatic bone. The zygomaticus minor

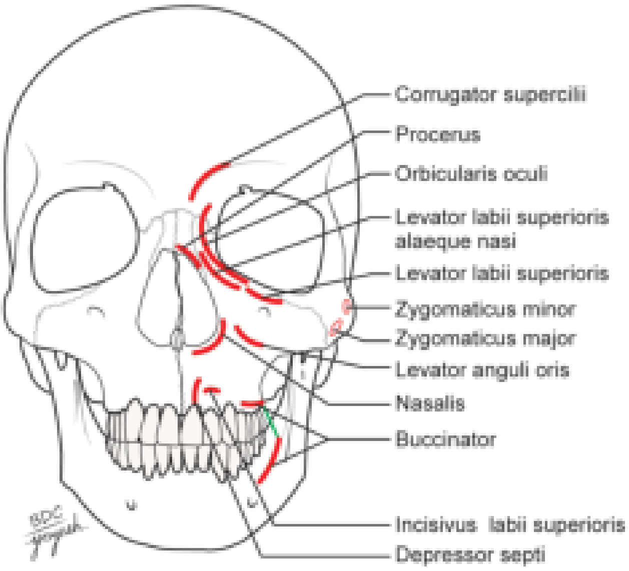

Corrugator supercilii
Procerus
Orbicularis oculi
Levator labii superioris alaeque nasi
Levator labii superioris
Zygomaticus minor
Zygomaticus major
Levator anguli oris
Nasalis
Buccinator
Incisivus labii superioris
Depressor septi
BDC

Fig. 1.5: Attachments of muscles to the norma frontalis

muscle arises below the zygomaticofacial foramen. The zygomaticus major arises lateral to the minor muscle.

11. Buccinator arises from maxilla and mandible opposite molar teeth and from *pterygomandibular raphe*. It also forms part of orbicularis oris.

Structures Passing Through Foramina

1. *Supraorbital notch or foramen* transmits the *supraorbital nerves and vessels*.
2. *External nasal nerve* emerges between the nasal bone and upper nasal cartilage.
3. *Infraorbital foramen* transmits the *infraorbital nerve* and *vessels*.
4. *Zygomaticofacial foramen* transmits the nerve of the same name, a branch of *maxillary nerve*.
5. *Mental foramen* on the mandible transmits the mental nerve and vessels.

CLINICAL ANATOMY

The *nasal bone is one of the most commonly fractured bones of the face*. Mandible and parietal eminence are the next bones to be fractured.

NORMA LATERALIS

Bones (Plate 1.3, Figs 1.6a and b, Flowchart 1.4)

1. Frontal
2. Parietal
3. Occipital
4. Temporal
5. Sphenoid
6. Zygomatic
7. Mandible
8. Maxilla
9. Nasal

Features

Temporal Lines

The *temporal lines* have been studied in the norma verticalis. The inferior temporal line, in its posterior part, turns downwards and forwards and becomes continuous with the ***supramastoid crest*** on the squamous temporal bone near its junction with the mastoid temporal. This crest is continuous anteriorly with the posterior root of the zygomatic arch (Flowchart 1.4, Plate 1.3, Figs 1.6a to c).

Zygomatic Arch or Zygoma

The *zygomatic arch* is a horizontal bar on the side of the head, in front of the ear, a little above the tragus. It is formed by the temporal process of the zygomatic bone in anterior 1/3rd and the zygomatic process of the temporal bone in posterior 2/3rd. The ***zygomaticotemporal suture*** crosses the arch obliquely downwards and backwards.

Features

1. The arch comprises 2 surfaces (medial and lateral) and 2 borders (upper and lower).
2. Medially, the arch is separated from the side of the skull by a gap, which is deeper in front than behind. The *lateral surface* of the arch is subcutaneous.
3. *Upper border* is continuous with temporal line in front and with supramastoid crest behind. The anterior end of the upper border is called the ***jugal point***.
4. The *posterior end* of the zygomatic arch is attached to the squamous temporal bone by *anterior* and *posterior roots*.
5. The ***tubercle of the root of the zygoma*** lies on its lower border at the junction of the anterior and posterior roots.

Flowchart 1.4: Features of norma lateralis

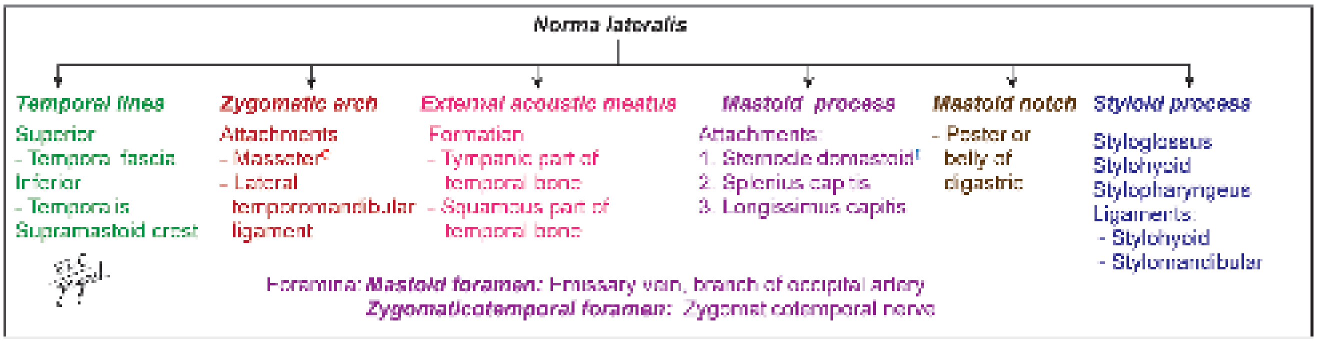
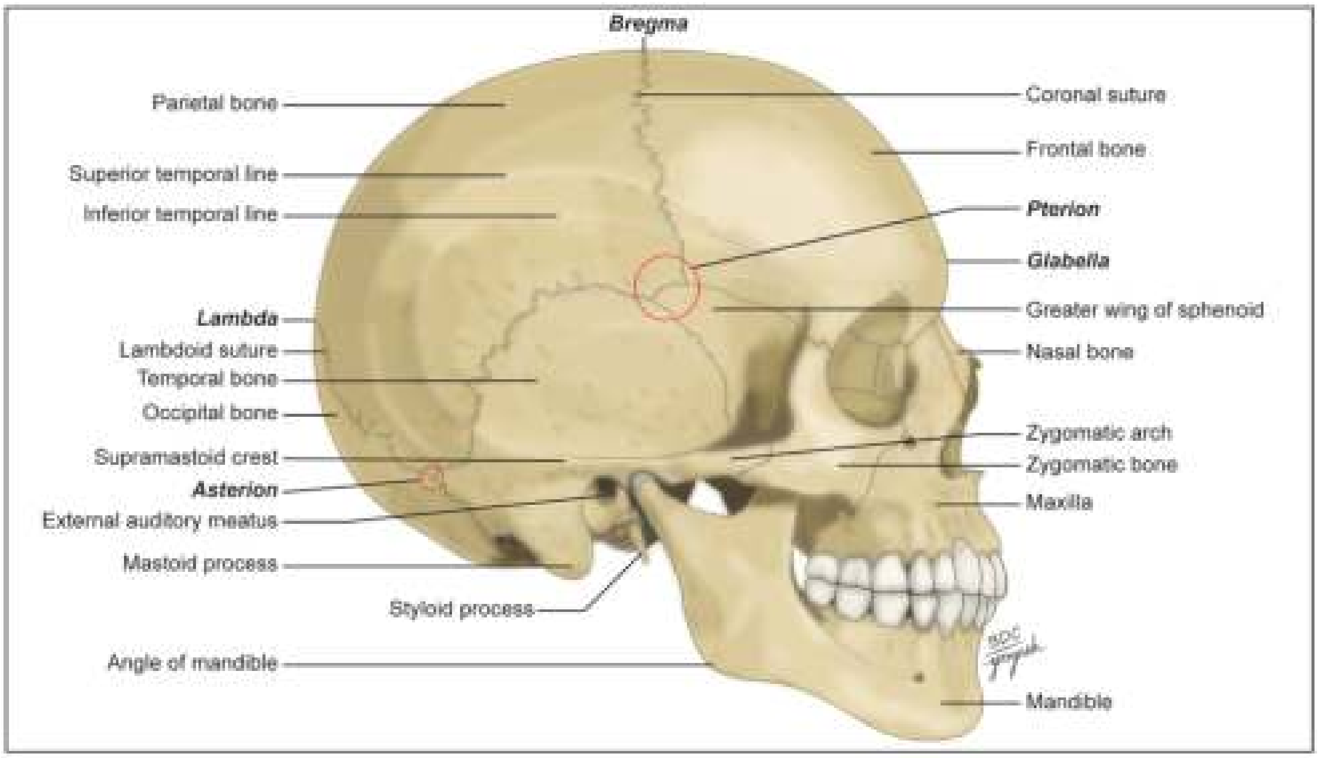
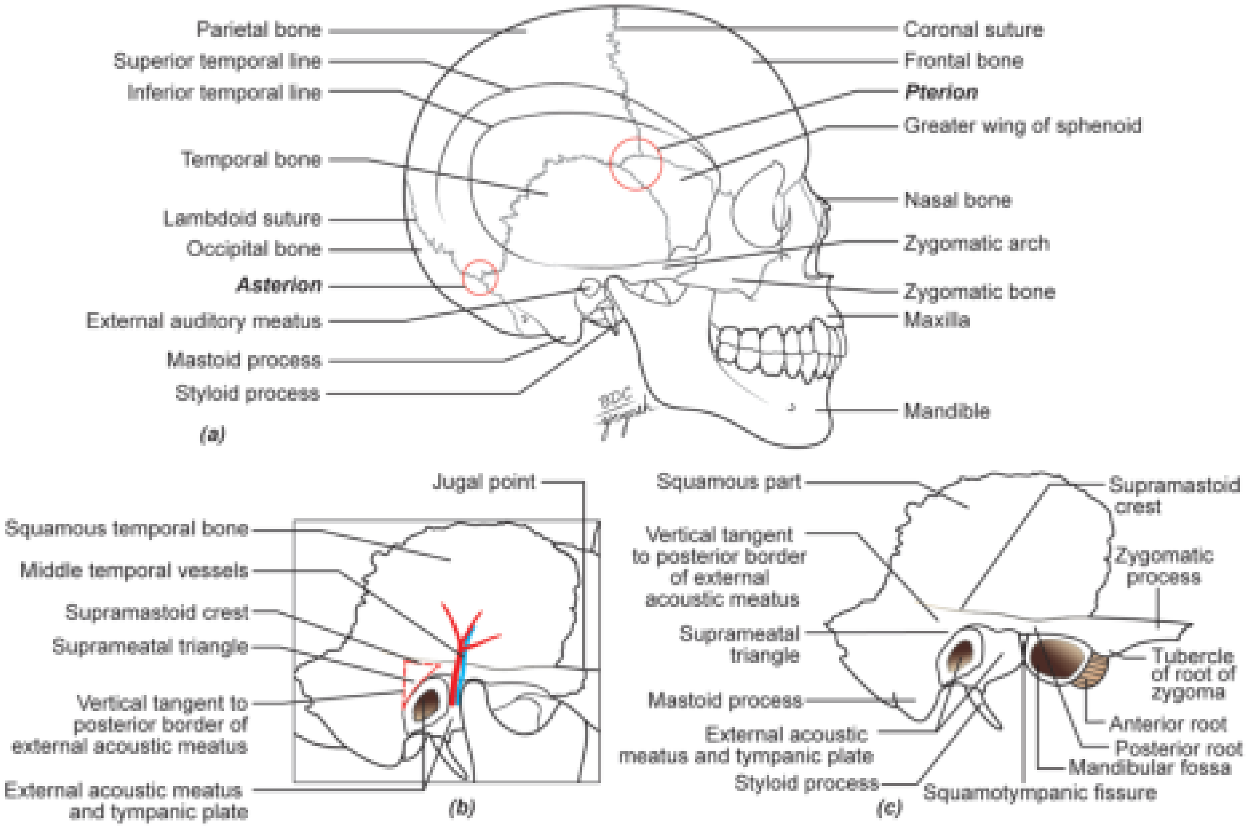

Norma lateralis
Temporal lines
Superior
- Temporal fascia
Inferior
- Temporalis
Supramastoid crest
Zygomatic arch
Attachments
- Masseter
- Lateral temporomandibular ligament
External acoustic meatus
Formation
- Tympanic part of temporal bone
- Squamous part of temporal bone
Mastoid process
Attachments:
1. Sternocleidomastoid
2. Splenius capitis
3. Longissimus capitis
Mastoid notch
- Posterior belly of digastric
Styloid process
Styloglossus
Stylohyoid
Stylopharyngeus
Ligaments:
- Stylohyoid
- Stylomandibular
Foramina: Mastoid foramen: Emissary vein, branch of occipital artery
Zygomaticotemporal foramen: Zygomaticotemporal nerve

Plate 1.3: Norma lateralis


Bregma
Parietal bone
Superior temporal line
Inferior temporal line
Lambda
Lambdoid suture
Temporal bone
Occipital bone
Supramastoid crest
Asterion
External auditory meatus
Mastoid process
Styloid process
Angle of mandible
Coronal suture
Frontal bone
Pterion
Glabella
Greater wing of sphenoid
Nasal bone
Zygomatic arch
Zygomatic bone
Maxilla
Mandible
BDC


Parietal bone
Superior temporal line
Inferior temporal line
Temporal bone
Lambdoid suture
Occipital bone
Asterion
External auditory meatus
Mastoid process
Styloid process
(a)
Coronal suture
Frontal bone
Pterion
Greater wing of sphenoid
Nasal bone
Zygomatic arch
Zygomatic bone
Maxilla
Mandible
BDC
Jugal point
Squamous temporal bone
Middle temporal vessels
Supramastoid crest
Suprameatal triangle
Vertical tangent to posterior border of external acoustic meatus
External acoustic meatus and tympanic plate
(b)
Squamous part
Vertical tangent to posterior border of external acoustic meatus
Suprameatal triangle
Mastoid process
External acoustic meatus and tympanic plate
Styloid process
Supramastoid crest
Zygomatic process
Tubercle of root of zygoma
Anterior root
Posterior root
Mandibular fossa
Squamotympanic fissure
(c)

Figs 1.6a to c: (a) Norma lateralis, (b) bones forming norma lateralis, and (c) tympanic plate forming margins of external acoustic meatus

6. The ***anterior root*** (articular tubercle) passes medially in front of the *mandibular fossa*. The ***posterior root*** passes backwards along the lateral margin of the mandibular or articular fossa, then above the external acoustic meatus to become continuous with the supramastoid crest.

7. Two projections are visible in relation to these roots.
   a. One is ***tubercle of root of zygoma*** at its lower border.
   b. Another tubercle is visible just behind the mandibular or articular fossa and is known as ***postglenoid tubercle***.

External Acoustic Meatus

1. The *external acoustic meatus* opens just below the posterior part of the posterior root of zygoma. Its anterior and inferior margins and the lower part of the posterior margin are formed by the tympanic plate, and the posterosuperior margin is formed by the squamous temporal bone. The margins are roughened for the attachment of auricular cartilage.
2. The ***suprameatal triangle*** *(triangle of Mc-Ewen)* is a small depression posterosuperior to the meatus. (Flowchart 1.5)

   Boundaries

   Superior: Supramastoid crest

   Anterior: Posterosuperior margin of external acoustic meatus

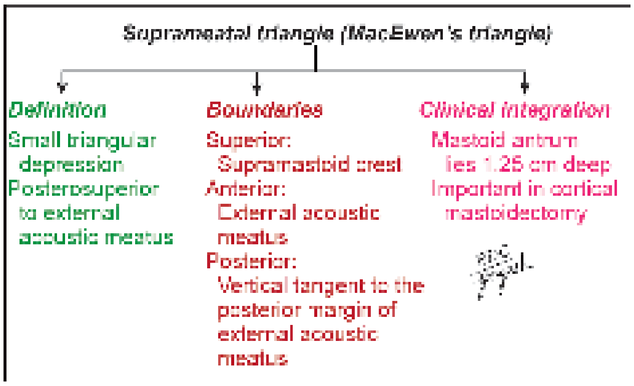
   Posterior: Vertical tangent to the posterior margin of the meatus.

   Clinical aspects: The triangle forms the lateral wall of the tympanic or mastoid antrum (Fig. 1.9c). The mastoid antrum lies 1.25 cm deep to the suprameatal triangle. This triangle is an important landmark in cortical mastoidectomy.
3. The ***suprameatal spine*** *(of Henle)* may be present on the anteroinferior margin of the triangle. It serves as a surgical landmark while performing middle ear surgeries.

Mastoid Part of the Temporal Bone

1. The *mastoid part of the temporal bone* lies just behind the external acoustic meatus.
2. The mastoid temporal bone articulates posterosuperiorly with the posteroinferior part of the parietal bone at the horizontal *parietomastoid suture,* and posteriorly with the squamous occipital bone at the *occipitomastoid suture.* These two sutures meet at the lateral end of the lambdoid suture. The ***asterion*** is the point where the parietomastoid, occipitomastoid and lambdoid sutures meet. In infants, the asterion is the site of the ***posterolateral*** **or** ***mastoid fontanelle***, which closes by 12 months (Fig. 1.3).

Flowchart 1.5: Suprameatal triangle


Suprameatal triangle (MacEwen's triangle)
Definition
Small triangular depression
Posterosuperior to external acoustic meatus
Boundaries
Superior:
Supramastoid crest
Anterior:
External acoustic meatus
Posterior:
Vertical tangent to the posterior margin of external acoustic meatus
Clinical integration
Mastoid antrum lies 1.25 cm deep
Important in cortical mastoidectomy

3. The ***mastoid process*** is a breast-like projection from the lower part of the mastoid temporal bone, posteroinferior to the external acoustic meatus. It appears during the 2nd year of life. The *tympanomastoid fissure* is placed on the anterior aspect of the base of the mastoid process. The *mastoid foramen* lies at or near the occipitomastoid suture (Fig. 1.5).

Styloid Process

The *styloid* (Latin *pen*) *process* is a needle-like thin, long projection from the temporal bone seen in norma basalis situated anteromedial to the mastoid process. It is directed downwards, forwards and slightly medially. Its base is partly ensheathed by the tympanic plate. The apex or tip is usually hidden from view by the posterior border of the ramus of the mandible.

Temporal Fossa

It is a shallow depression on the side of the skull.

Boundaries

1. *Above:* Superior temporal line.
2. *Below:* Upper border of the zygomatic arch laterally, and by the infratemporal crest of the greater wing of the sphenoid bone medially. Through the gap deep to the zygomatic arch, temporal fossa communicates with the infratemporal fossa.
3. *Anterior wall:* Formed by the zygomatic bone and by parts of the frontal and sphenoid bones. This wall separates the fossa from the orbit.
4. *Floor:* The anterior part of the floor is crossed by an H-shaped suture where four bones—frontal, parietal, greater wing of sphenoid and temporal adjoin each other. This area is termed the ***pterion***.

Note:

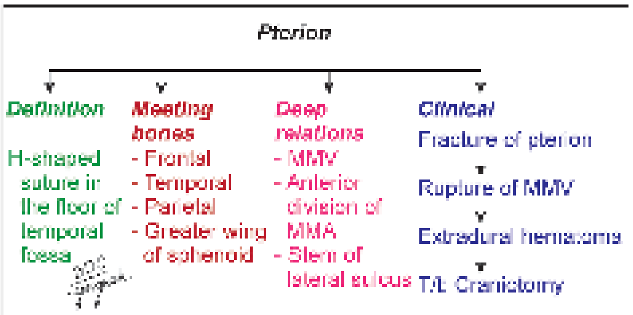
The ***pterion*** lies 4 cm above the midpoint of the zygomatic arch and 2.5 cm behind the frontozygomatic suture. Deep to the pterion lie, *middle meningeal vein*, *anterior division of the middle meningeal artery* and *stem of the lateral sulcus of brain (Sylvian point)* (Flowchart 1.6).

On the temporal surface of the zygomatic bone forming the anterior wall of the fossa, there is the *zygomaticotemporal foramen.*

Attachments (Fig. 1.7)

1. Temporal fascia is attached to the superior temporal line and to the area between the two temporal lines. Inferiorly, it is attached to the outer and inner lips of the upper border of the zygomatic arch.
2. Temporalis muscle arises from the whole of the temporal fossa.
3. The medial surface and lower border of the zygomatic arch give origin to the masseter.
4. Lateral ligament of the temporomandibular joint is attached to the tubercle of the root of the zygoma.
5. The sternocleidomastoid, splenius capitis and longissimus capitis are inserted from before backwards on the posterior part of the lateral surface of the mastoid process. Posterior belly of digastric arises from mastoid notch. The groove obliquely placed behind mastoid notch is due to occipital artery.

Flowchart 1.6: Pterion


Pterion
Definition
H-shaped suture in the floor of temporal fossa
Meeting bones
- Frontal
- Temporal
- Parietal
- Greater wing of sphenoid
Deep relations
- MMV
- Anterior division of MMA
- Stem of lateral sulcus
Clinical
Fracture of pterion
Rupture of MMV
Extradural hematoma
T/t: Craniotomy

(MAA: Middle meningeal artery, MMV: Middle meningeal vein)

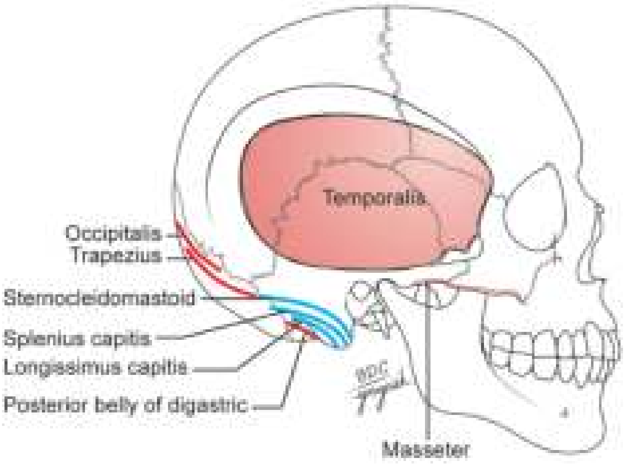

Temporalis
Occipitalis
Trapezius
Sternocleidomastoid
Splenius capitis
Longissimus capitis
Posterior belly of digastric
Masseter

Fig. 1.7: Attachments of norma lateralis

6. The *gap* between the zygomatic arch and the side of the skull transmits:
   a. Tendon of the temporalis muscle
   b. Deep temporal vessels
   c. Deep temporal nerves
   d. Zygomaticotemporal vessels and nerve

Note: For infratemporal fossa, *see* Chapter 6. For pterygopalatine fossa, *see* Chapter 15.

Structures Passing Through Foramina

1. *Tympanomastoid fissure* on the anterior aspect of the base of the mastoid process transmits the *auricular branch* of *vagus nerve.*
2. Mastoid foramen transmits:
   a. *Emissary vein* connecting the *sigmoid sinus* with the *posterior auricular vein* (Table 1.1).
   b. Meningeal branch of the occipital artery.
3. *Zygomaticotemporal foramen* transmits the nerve of the same name and a minute artery.

CLINICAL ANATOMY

Pterion*, the site of anterolateral fontanelle,* is the thin part of skull. In roadside accidents, the anterior division of middle meningeal artery at pterion (Fig. 1.8) may be ruptured, leading to clot formation between the skull bone and dura mater or extradural haemorrhage (Fig. 1.9). The clot compresses the motor area of brain, leading to paralysis of the opposite side. The clot must be sucked out at the earliest by trephining. The head must be protected by a helmet during driving a two-wheeler.

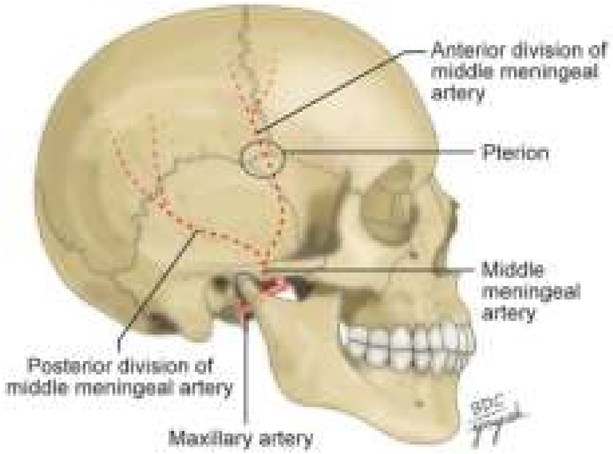

Anterior division of middle meningeal artery
Pterion
Middle meningeal artery
Posterior division of middle meningeal artery
Maxillary artery

Fig. 1.8: Position of anterior division of middle meningeal artery against the pterion

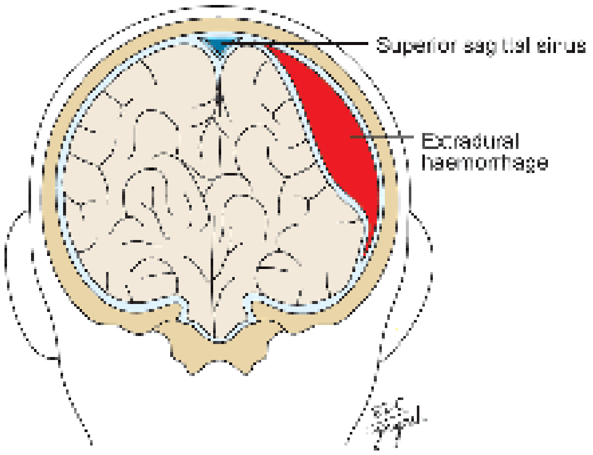

Superior sagittal sinus
Extradural haemorrhage

Fig. 1.9: Extradural haemorrhage

NORMA BASALIS

The inferior view of the skull is norma basalis. For the descriptive purposes, the norma basalis is divided into anterior, middle and posterior parts by two imaginary transverse lines:

1. ***Anterior transverse line:*** It passes along the posterior margin of the hard palate.
2. ***Posterior transverse line:*** It passes along the anterior margin of the foramen magnum (Plate 1.4, Fig. 1.10).

Anterior Part of Norma Basalis

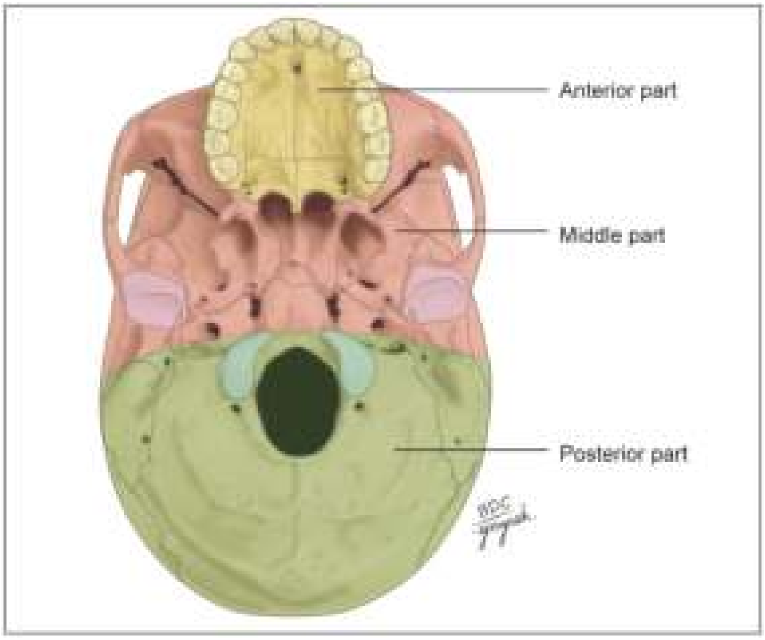
The anterior part of norma basalis consists of two parts (Plate 1.5, Flowchart 1.7):

1. Alveolar processes of maxillae or alveolar arch
2. Hard palate

Alveolar Arch

Alveolar processes of maxillae form U-shaped alveolar arch that bears sockets for the roots of the upper teeth.

Plate 1.4: Parts of norma basalis


Anterior part
Middle part
Posterior part
BDC
gargnik

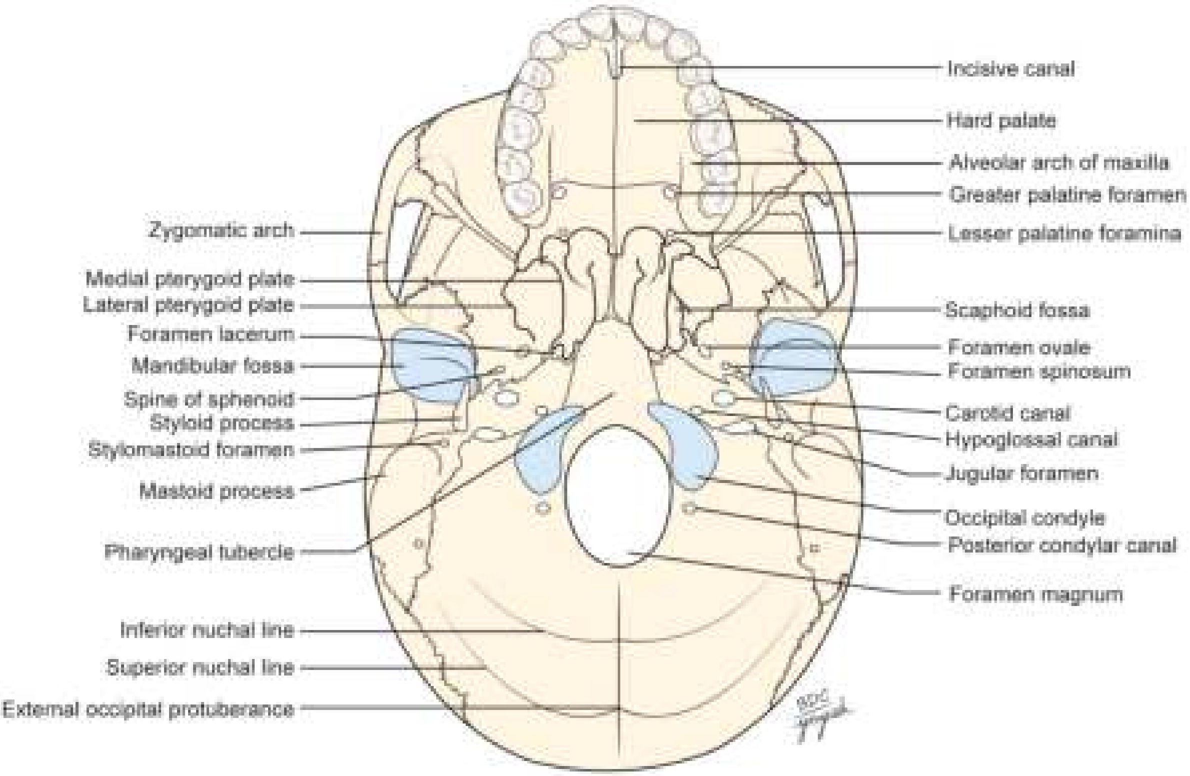
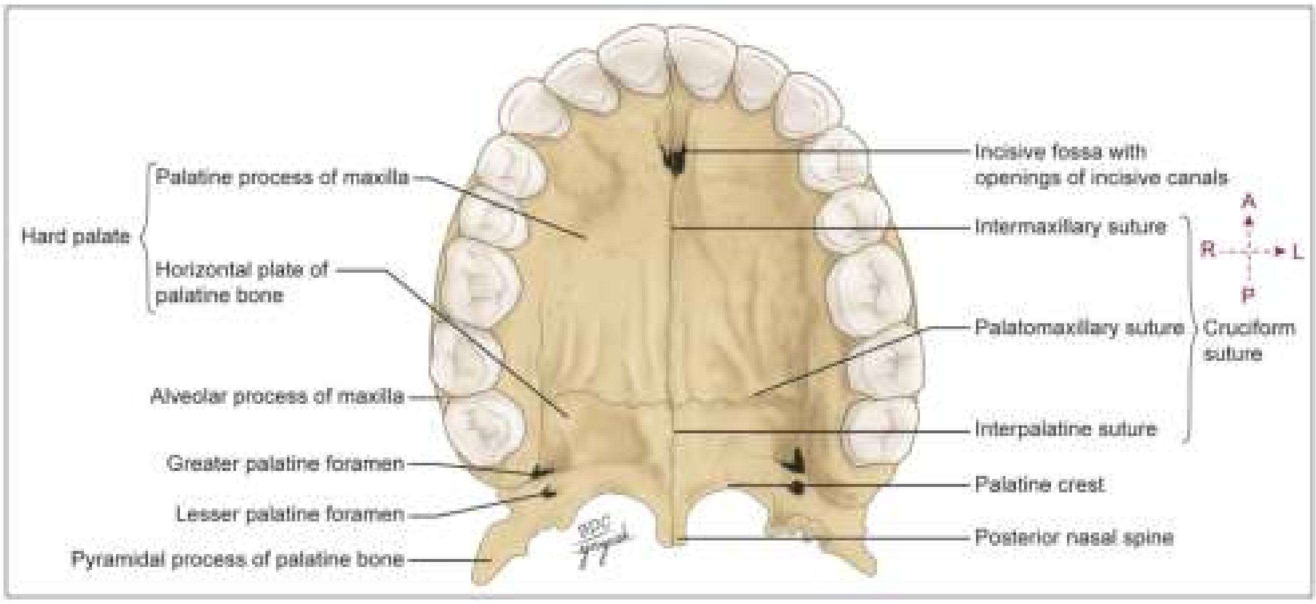

Incisive canal
Hard palate
Alveolar arch of maxilla
Greater palatine foramen
Lesser palatine foramina
Zygomatic arch
Medial pterygoid plate
Lateral pterygoid plate
Foramen lacerum
Mandibular fossa
Spine of sphenoid
Styloid process
Stylomastoid foramen
Mastoid process
Pharyngeal tubercle
Scaphoid fossa
Foramen ovale
Foramen spinosum
Carotid canal
Hypoglossal canal
Jugular foramen
Occipital condyle
Posterior condylar canal
Foramen magnum
Inferior nuchal line
Superior nuchal line
External occipital protuberance
BDC
gargnik

Fig. 1.10: Norma basalis

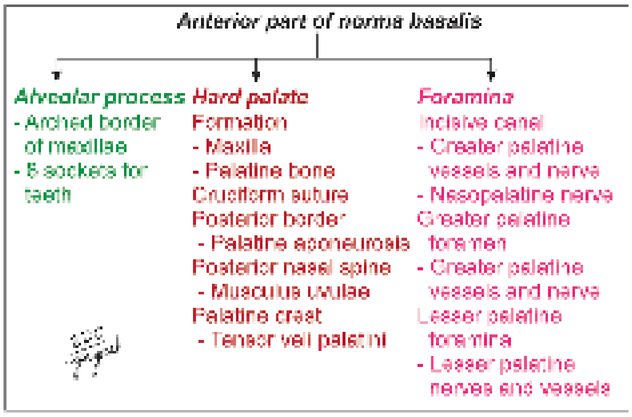
Hard Palate

1. *Formation:*
   a. Anterior 2/3rd, by the palatine processes of the maxillae.
   b. Posterior 1/3rd, by the horizontal plates of the palatine bones.
2. *Sutures:* The palate is crossed by a cruciform suture made up of intermaxillary, interpalatine and palatomaxillary sutures.
3. It is arched in all directions. It shows pits for the palatine glands.
4. The *posterior border* of the hard palate is free and presents the ***posterior nasal spine*** in the median plane.
5. The ***palatine crest*** is a curved ridge near the posterior border. It begins behind the greater palatine foramen and runs medially.
6. ***Incisive foramen*** is a deep fossa situated anteriorly in the median plane. Two ***incisive canals***, right and left,

Plate 1.5: Anterior part of norma basalis


Hard palate
Palatine process of maxilla
Horizontal plate of palatine bone
Alveolar process of maxilla
Greater palatine foramen
Lesser palatine foramen
Pyramidal process of palatine bone
Incisive fossa with openings of incisive canals
Intermaxillary suture
Palatomaxillary suture
Interpalatine suture
Cruciform suture
Palatine crest
Posterior nasal spine
A
R
L
P

Flowchart 1.7: Features of anterior part of norma basalis


Anterior part of norma basalis
Alveolar process
- Arched border of maxillae
- 8 sockets for teeth
Hard palate
Formation
- Maxilla
- Palatine bone
Cruciform suture
Posterior border
- Palatine aponeurosis
Posterior nasal spine
- Musculus uvulae
Palatine crest
- Tensor veli palatini
Foramina
Incisive canal
- Greater palatine vessels and nerve
- Nasopalatine nerve
Greater palatine foramen
- Greater palatine vessels and nerve
Lesser palatine foramina
- Lesser palatine nerves and vessels

pierce the walls of the incisive foramen, usually one on each side, but occasionally in the median plane, the left being anterior and the right, posterior.

7. ***Greater palatine foramen***, one on each side, is situated just behind the lateral part of the palatomaxillary suture. A groove leads from the foramen towards the incisive fossa.
8. ***Lesser palatine foramina***, two or three in number on each side, lie behind the greater palatine foramen and perforate the pyramidal process of the palatine bone.

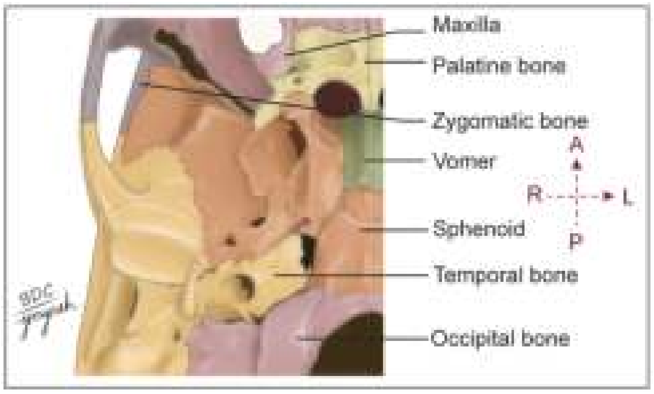
Middle Part of Norma Basalis

The middle part extends from the posterior border of the hard palate to the arbitrary transverse line passing through the anterior margin of the foramen magnum. Middle part of the norma basalis is studied as median and lateral areas (Plates 1.6 and 1.7).

Median Area

1. The median area shows (Flowchart 1.8):
   a. Posterior border of the *vomer*.

Plate 1.6: Bones of middle part of norma basalis


Maxilla
Palatine bone
Zygomatic bone
Vomer
Sphenoid
Temporal bone
Occipital bone
A
R
L
P

   b. A *broad bar of bone* formed by fusion of the posterior part of the body of sphenoid and the basilar part of occipital bone.
2. The ***vomer*** separates the two posterior nasal apertures. Its inferior border articulates with the bony palate. The superior border splits into two ***alae*** and articulates with the ***rostrum*** of the *sphenoid bone* (Fig. 1.11).

Flowchart 1.8: Features of median area of middle part of norma basalis

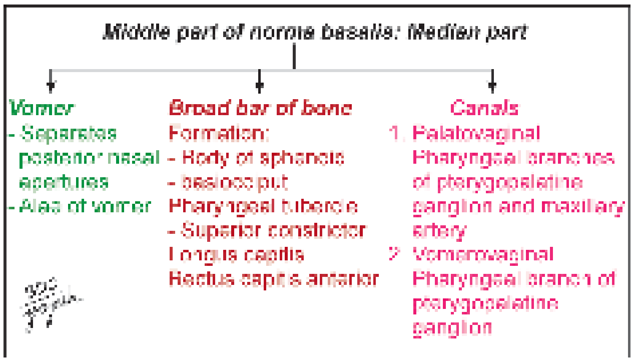
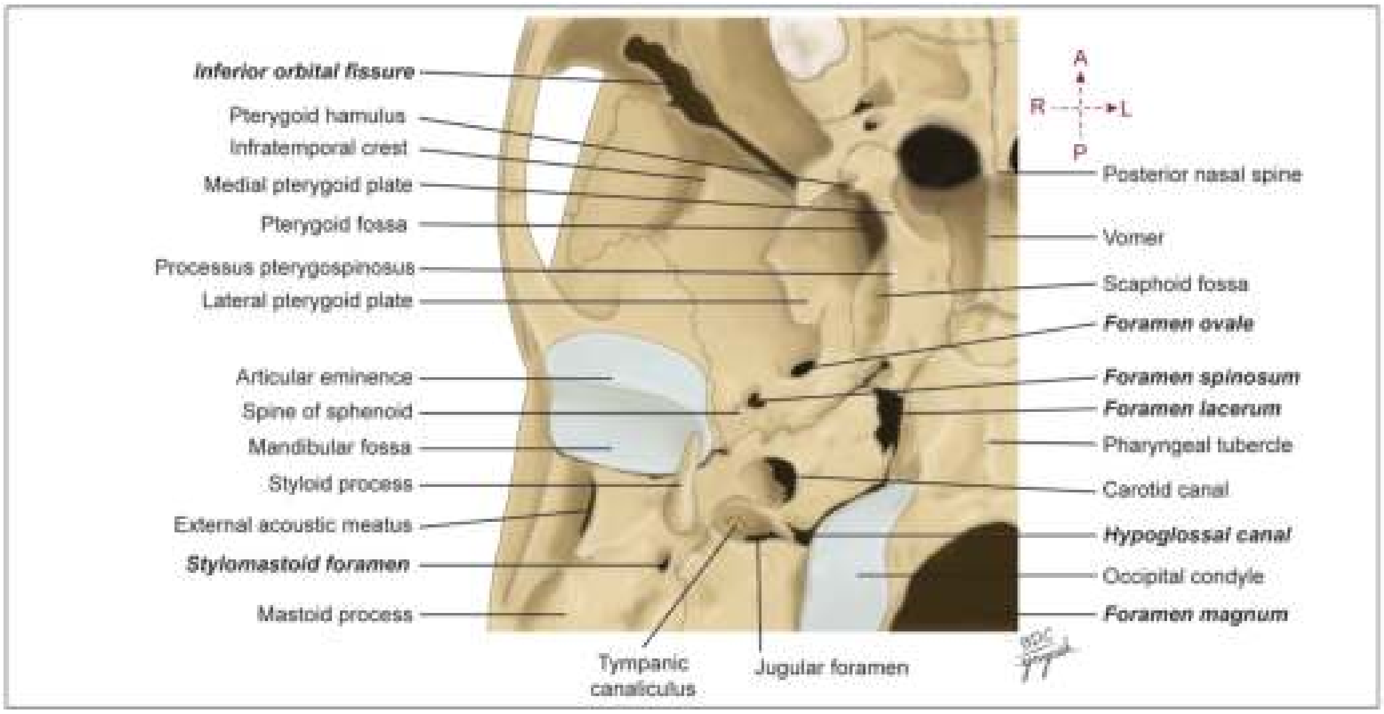

Middle part of norma basalis: Median part
Vomer
- Separates posterior nasal apertures
- Alae of vomer
Broad bar of bone
Formation:
- Body of sphenoid
- basiocciput
Pharyngeal tubercle
- Superior constrictor
Longus capitis
Rectus capitis anterior
Canals
1. Palatovaginal
Pharyngeal branches of pterygopalatine ganglion and maxillary artery
2. Vomerovaginal
Pharyngeal branch of pterygopalatine ganglion

Plate 1.7: Features of middle part of norma basalis


Inferior orbital fissure
Pterygoid hamulus
Infratemporal crest
Medial pterygoid plate
Pterygoid fossa
Processus pterygospinosus
Lateral pterygoid plate
Articular eminence
Spine of sphenoid
Mandibular fossa
Styloid process
External acoustic meatus
Stylomastoid foramen
Mastoid process
Tympanic canaliculus
Jugular foramen
A
R
L
P
Posterior nasal spine
Vomer
Scaphoid fossa
Foramen ovale
Foramen spinosum
Foramen lacerum
Pharyngeal tubercle
Carotid canal
Hypoglossal canal
Occipital condyle
Foramen magnum

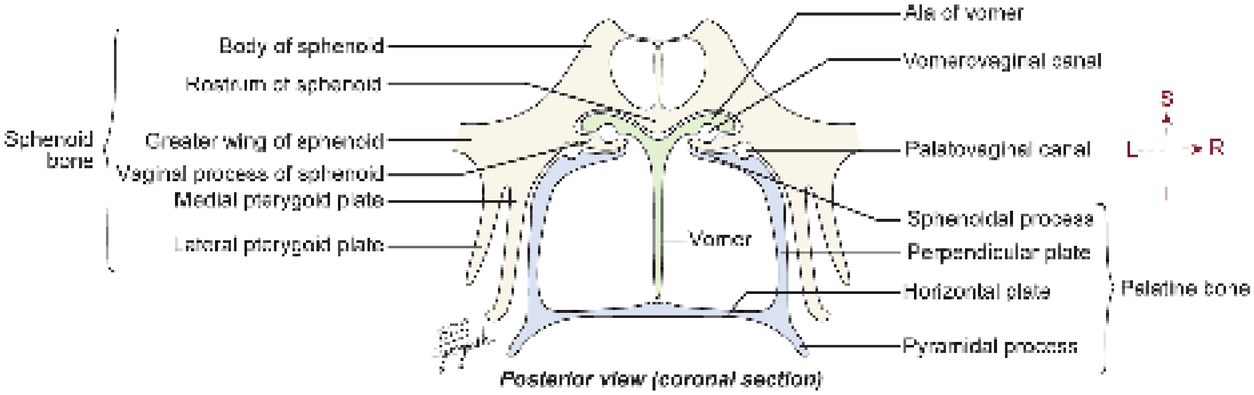

Sphenoid bone
Body of sphenoid
Rostrum of sphenoid
Greater wing of sphenoid
Vaginal process of sphenoid
Medial pterygoid plate
Lateral pterygoid plate
Vomer
Ala of vomer
Vomerovaginal canal
Palatovaginal canal
Sphenoidal process
Perpendicular plate
Horizontal plate
Pyramidal process
Palatine bone
S
L
R
I
Posterior view (coronal section)

Fig. 1.11: Vomerovaginal and palatovaginal canals

3. The broad bar of the bone is marked in the median plane by the ***pharyngeal tubercle***, a little in front of the foramen magnum (Plate 1.8).

Note:

Palatinovaginal canal: The inferior surface of the vaginal process of the medial pterygoid plate is marked by an anteroposterior groove, which is converted into the palatinovaginal canal by the upper surface of the sphenoidal process of the palatine bone. The canal opens anteriorly into the posterior wall of the pterygopalatine fossa (Fig. 1.11).

Vomerovaginal canal: The lateral border of each ala of the vomer comes into relationship with the vaginal process of the medial pterygoid plate, and may overlap it from above to enclose the vomerovaginal canal (Fig. 1.11).

Lateral Area

The lateral area shows (Plate 1.8, Flowchart 1.9)

a. Two parts of the sphenoid bone — pterygoid process and greater wing.
b. Three parts of the temporal bone — petrous temporal, tympanic plate and squamous temporal.

1. **Pterygoid process** projects downwards from the junction of greater wing and the body of sphenoid behind the third molar tooth.

   Inferiorly, it divides into the *medial and lateral pterygoid plates*, which are fused together anteriorly, but are separated posteriorly by the V-shaped *pterygoid fossa.*

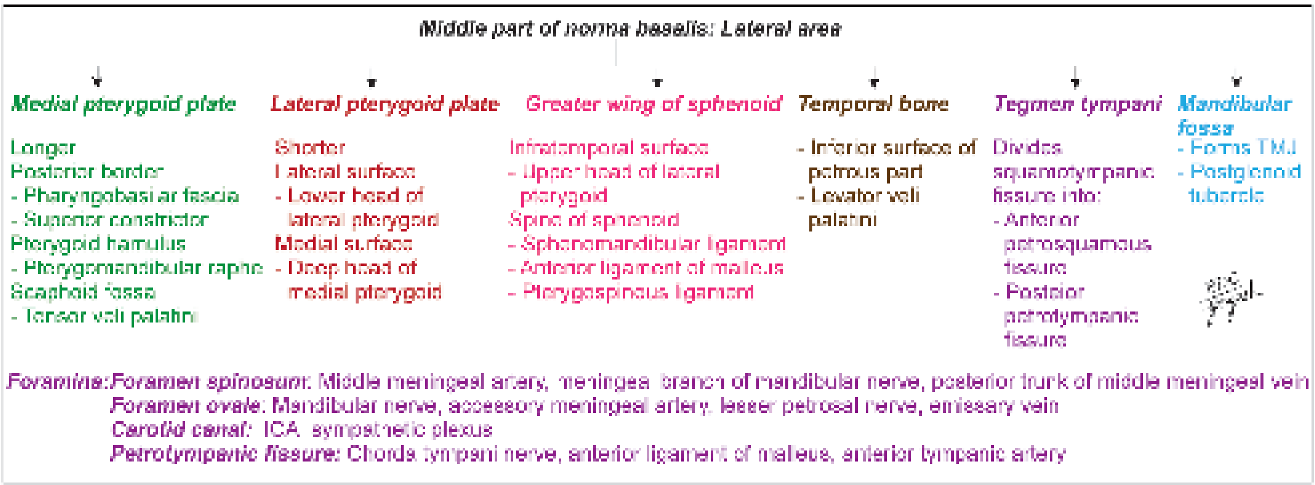
   The fused anterior borders of the two plates articulate medially with the perpendicular plate of the palatine bone, and are separated laterally from the posterior surface of the body of the maxilla by the *pterygomaxillary fissure*.

2. **Medial pterygoid plate**

   It is directed backwards. It has medial and lateral surfaces and a free posterior border.

   The upper end of posterior border divides to enclose a triangular depression called the ***scaphoid fossa***.

Flowchart 1.9: Features of lateral area of middle part of norma basalis


Middle part of norma basalis: Lateral area
Medial pterygoid plate
Longer
Posterior border
- Pharyngobasilar fascia
- Superior constrictor
Pterygoid hamulus
- Pterygomandibular raphe
Scaphoid fossa
- Tensor veli palatini
Lateral pterygoid plate
Shorter
Lateral surface
- Lower head of lateral pterygoid
Medial surface
- Deep head of medial pterygoid
Greater wing of sphenoid
Infratemporal surface
- Upper head of lateral pterygoid
Spine of sphenoid
- Sphenomandibular ligament
- Anterior ligament of malleus
- Pterygospinous ligament
Temporal bone
- Inferior surface of petrous part
- Levator veli palatini
Tegmen tympani
Divides squamotympanic fissure into:
- Anterior petrosquamous fissure
- Posterior petrotympanic fissure
Mandibular fossa
- Forms TMJ
- Postglenoid tubercle
Foramina: Foramen spinosum: Middle meningeal artery, meningeal branch of mandibular nerve, posterior trunk of middle meningeal vein
Foramen ovale: Mandibular nerve, accessory meningeal artery, lesser petrosal nerve, emissary vein
Carotid canal: ICA, sympathetic plexus
Petrotympanic fissure: Chorda tympani nerve, anterior ligament of malleus, anterior tympanic artery

The lower end of the posterior border is prolonged downwards and laterally to form the ***pterygoid hamulus***.

3. **Lateral pterygoid plate**

   It is directed backwards and laterally. It has medial and lateral surfaces and a free posterior border.

   The posterior border sometimes has a projection at its middle called the *pterygospinous process*, which projects towards the spine of the sphenoid.

4. **Infratemporal surface of the greater wing of the sphenoid**

   It is pentagonal.

   It shows the following 4 foramina:

   a. ***Foramen ovale*** is large and oval. It is situated posterolateral to the upper end of the posterior border of lateral pterygoid plate.

   b. ***Foramen spinosum*** is small and circular in shape. It is situated posterolateral to the foramen ovale, and is limited posterolaterally by the spine of sphenoid.

   c. Sometimes, there is the ***emissary sphenoidal foramen*** *or foramen of Vesalius*. It is situated between the foramen ovale and the scaphoid fossa. Internally, it opens between the foramen ovale and the foramen rotundum.

   d. At times, there is a ***canaliculus innominatus*** situated between the foramen ovale and the foramen spinosum.

   There is a small, sharp, downward projection between the posterolateral and posteromedial margins called the ***spine of the sphenoid***.

   Sulcus tubae is the groove between the posteromedial margin of the greater wing of the sphenoid and the petrous temporal bone. It lodges the *cartilaginous part of the auditory tube*. Posteriorly, the groove leads to the bony part of the auditory tube, which lies within the petrous temporal bone.

5. **Inferior surface of the *petrous* part of the temporal bone** is triangular in shape with its apex directed forwards and medially (Greek petrous = *rock*). It lies between the greater wing of the sphenoid and the basiocciput.

   Its *apex* is perforated by the upper end of the carotid canal, and is separated from the sphenoid by the foramen lacerum. The *inferior surface* is perforated by the lower end of the *carotid canal* posteriorly.

   Carotid canal runs forwards and medially within the petrous temporal bone.

   Tegmen tympani: It is a part of the petrous temporal bone that is present in the middle cranial fossa. It has a down turned edge, which is seen in the *squamotympanic fissure* and divides it into the posterior *petrotympanic* and anterior *petrosquamous* fissures.

6. ***Foramen lacerum*** is a short, wide canal, 1 cm long.

   Its lower end is bounded posterolaterally by the apex of the petrous temporal, medially by the basiocciput and the body of the sphenoid and anteriorly by the root of the pterygoid process and the greater wing of the sphenoid bone (Fig. 1.13).

7. ***Tympanic part of the temporal bone****, also called the* ***tympanic plate***, is a triangular curved plate, which lies in the angle between the petrous and squamous parts. Its apex is directed medially and lies close to the spine of the sphenoid.

   The *base or lateral border* is curved, free and roughened.

   Its *anterior surface* forms the posterior wall of the mandibular fossa. The *posterior surface* is concave and forms the anterior wall, floor and lower part of the posterior wall of the bony external acoustic meatus.

   Its *upper border* bounds the petrotympanic fissure.

   The *lower border* is sharp and free.

   Medially, the tympanic plate passes along the anterolateral margin of the lower end of the carotid canal. Laterally, it forms the anterolateral part of the *sheath of the styloid process*. Internally, the tympanic plate is fused to the petrous temporal bone.

8. ***Squamous part of the temporal bone*** forms:

   a. The anterior part of the mandibular/articular fossa, which articulates with the head of the mandible to form the temporomandibular joint.

b. The tubercle of root of zygoma, which is continuous with the anterior root of the zygoma.
c. A small posterolateral part of the roof of the infratemporal fossa.

Posterior Part of Norma Basalis

The posterior part of norma basalis is studied as median and lateral areas (Plate 1.8, Flowchart 1.10).

Median Area

The median area shows the following four features from before backwards:

1. Foramen magnum
2. External occipital crest
3. External occipital protuberance
4. Nuchal lines.

1. ***Foramen magnum*** (Latin *great*) is the largest foramen of the skull. It opens upwards into the posterior cranial fossa, and downwards into the vertebral canal. It is oval in shape, being wider behind than in front where it is overlapped on each side by the occipital condyles.
2. ***External occipital crest*** begins at the posterior margin of the foramen magnum and ends posteriorly and above at the external occipital protuberance.
3. ***External occipital protuberance*** is a projection located at the posterior end of the crest. It is easily felt in the living, in the midline, at the point where the back of the neck becomes continuous with the scalp.
4. ***Nuchal lines*****:** These are superior, inferior and the highest. The *superior nuchal lines* begin at the external occipital protuberance and the *inferior nuchal lines* at the middle of the crest. Both of them curve laterally and backwards and then laterally and forwards.

   Highest nuchal line is faded and seen above superior nuchal line (occasionally).

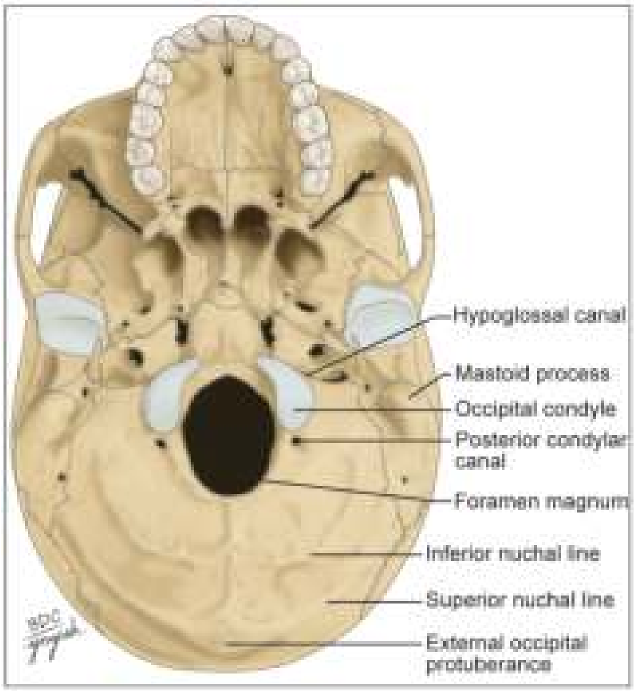
Lateral Area

The *lateral area* shows:

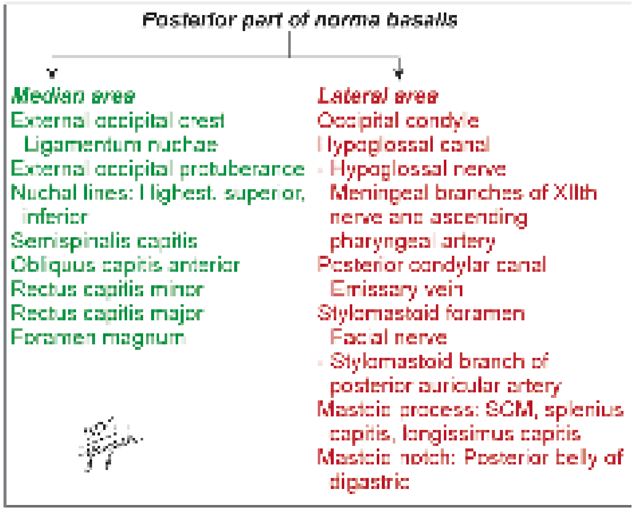
- Condylar part of the occipital bone
- Squamous part of the occipital bone
- Jugular foramen between the occipital and petrous temporal bones
- Styloid process of the temporal bone
- Mastoid part of the temporal bone.

1. ***Condylar or lateral part of the occipital bone*** presents the following features:
   - ***Occipital condyles*** are oval in shape and are situated on each side of the anterior part of the foramen magnum. Their long axis is directed forwards and medially. They articulate with the superior articular facets of the atlas vertebra to form the *atlanto-occipital joints*.
   - ***Hypoglossal canal*** or *anterior condylar canal* pierces the bone anterosuperior to the occipital condyle, and is directed laterally and slightly forwards.

Plate 1.8: Norma basalis – Posterior part labelled


Hypoglossal canal
Mastoid process
Occipital condyle
Posterior condylar canal
Foramen magnum
Inferior nuchal line
Superior nuchal line
External occipital protuberance

Flowchart 1.10: Features of posterior part of norma basalis


Posterior part of norma basalis
Median area
External occipital crest
Ligamentum nuchae
External occipital protuberance
Nuchal lines: Highest, superior, inferior
Semispinalis capitis
Obliquus capitis anterior
Rectus capitis minor
Rectus capitis major
Foramen magnum
Lateral area
Occipital condyle
Hypoglossal canal
Hypoglossal nerve
Meningeal branches of XIIth nerve and ascending pharyngeal artery
Posterior condylar canal
Emissary vein
Stylomastoid foramen
Facial nerve
Stylomastoid branch of posterior auricular artery
Mastoid process: SCM, splenius capitis, longissimus capitis
Mastoid notch: Posterior belly of digastric

   - ***Condylar canal*** or *posterior condylar canal* is occasionally present in the floor of a condylar fossa present behind the occipital condyle. Superiorly, it opens into the sigmoid sulcus.
   - ***Jugular process of the occipital bone*** lies lateral to the occipital condyle and forms the posterior boundary of jugular foramen.
2. ***Squamous part of occipital bone*** is marked by the superior and inferior nuchal lines mentioned above (Fig. 1.3).
3. ***Jugular foramen*** is large and elongated, with its long axis directed forwards and medially. It is placed at the posterior end of the petro-occipital suture.
4. ***Styloid process*** is described in Chapter 8, page 161. ***Stylomastoid foramen*** is situated between the anterior end of mastoid process and root of styloid process.

5. ***Mastoid process***, a component of mastoid part is a large conical projection located posterolateral to the stylomastoid foramen. It is directed downwards and forwards. It forms the lateral wall of the *mastoid notch*.

Note:

At the posterior end of the foramen, its anterior wall (petrous temporal) is hollowed out to form ***jugular fossa***, which lodges the superior bulb of the internal jugular vein. The fossa is larger on the right side than on the left.

The lateral wall of the jugular fossa is pierced by a minute canal, the ***mastoid canaliculus*** *(Arnold's canal)*. It transmits the auricular branch of vagus nerve or Arnold's nerve.

Near the medial end of the jugular foramen, there is the ***jugular notch***. At the apex of the notch, there is an opening that leads into the ***cochlear canaliculus***.

Tympanic canaliculus opens on or near the thin edge of bone between the jugular fossa and the lower end of the carotid canal.

Attachments (Fig. 1.12)

1. Palate
2. Posterior border of the hard palate provides attachment to the palatine aponeurosis. The posterior nasal spine gives origin to the musculus uvulae.

   Palatine crest provides attachment to a part of the tendon of tensor veli palatini muscle.
3. Inferior surface of the basiocciput:
   a. *Pharyngeal tubercle* gives attachment to the raphe, which provides insertion to the upper fibres of the superior constrictor muscle of the pharynx.
   b. The area in front of the tubercle forms the roof of the *nasopharynx* and supports the *pharyngeal tonsil*.
   c. Longus capitis is inserted lateral to the pharyngeal tubercle.
   d. Rectus capitis anterior is inserted a little posterior and medial to the hypoglossal canal.
4. Medial pterygoid plate:
   a. Lower part of the posterior border and the pterygoid hamulus give origin to the superior constrictor of the pharynx.
   b. Upper part of the posterior border is notched by the *auditory* tube.
   c. Pterygomandibular raphe is attached to the tip of the *pterygoid hamulus* at one end and to the mandible behind 3rd molar tooth at the other end.
5. Lateral pterygoid plate:
   a. Its lateral surface gives origin to the larger lower head of lateral pterygoid muscle.
   b. Its medial surface gives origin to the deep head of the medial pterygoid. The small, superficial head of this muscle arises from the *maxillary tuberosity* and the adjoining part of the pyramidal process of the palatine bone.
   c. Pharyngobasilar fascia is attached below to the processus tuberis.

      Processus tuberis/pterygospinous process (Civinini's ligament) is a triangular projection, which is present at the middle of the posterior border of lateral pterygoid plate. It supports the medial end of cartilaginous part of auditory tube.
   d. The pterygospinous process, which is present at the middle of lateral pterygoid plate gives attachment to the ligament of same name.

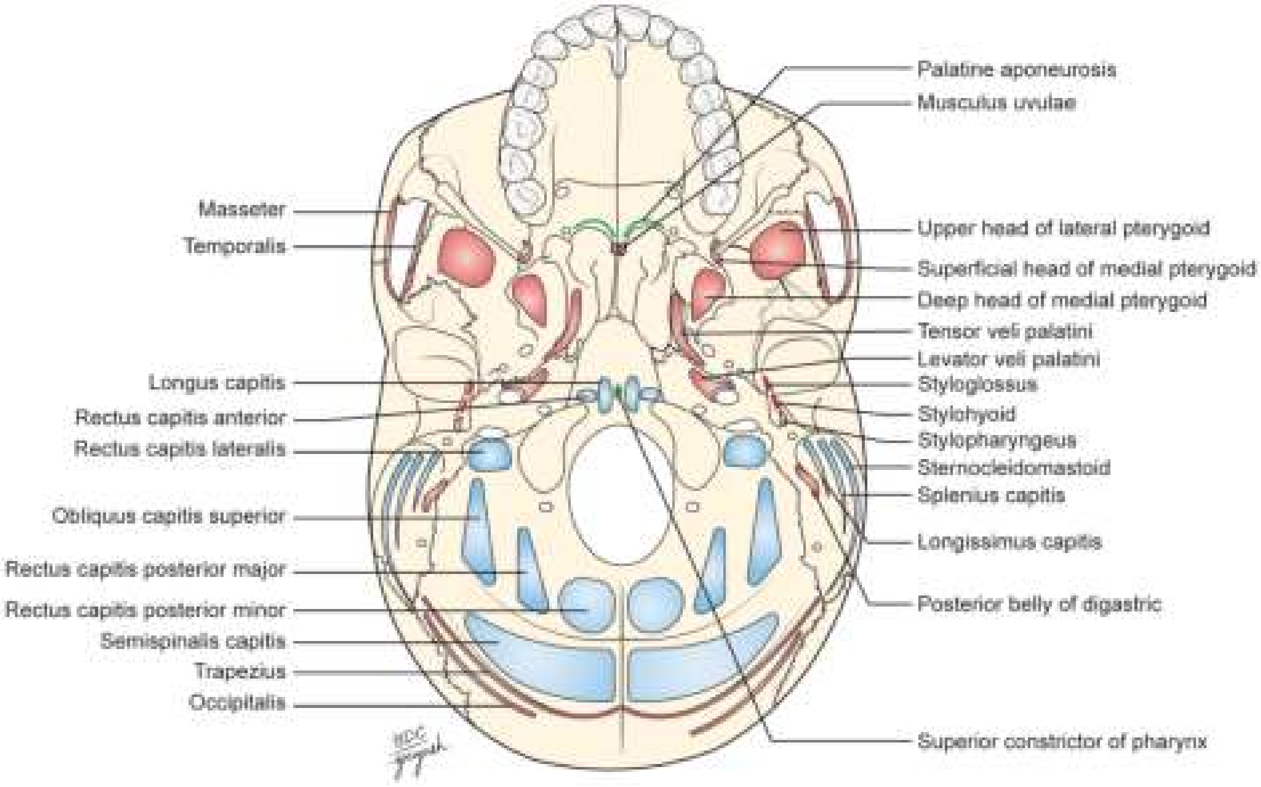

Masseter
Temporalis
Longus capitis
Rectus capitis anterior
Rectus capitis lateralis
Obliquus capitis superior
Rectus capitis posterior major
Rectus capitis posterior minor
Semispinalis capitis
Trapezius
Occipitalis
Palatine aponeurosis
Musculus uvulae
Upper head of lateral pterygoid
Superficial head of medial pterygoid
Deep head of medial pterygoid
Tensor veli palatini
Levator veli palatini
Styloglossus
Stylohyoid
Stylopharyngeus
Sternocleidomastoid
Splenius capitis
Longissimus capitis
Posterior belly of digastric
Superior constrictor of pharynx

Fig. 1.12: Muscles attached to the base of skull

6. Infratemporal surface of the greater wing of the sphenoid: It gives origin to the upper head of the lateral pterygoid muscle, and is crossed by the deep temporal and masseteric nerves.
7. *Spine of the sphenoid:* It is related laterally to the auriculotemporal nerve, and medially to the chorda tympani nerve and auditory tube.

   Its *tip* provides attachment to sphenomandibular ligament, anterior ligament of malleus and pterygospinous ligament.

   Its *anterior aspect* gives origin to the most posterior fibres of the tensor veli palatini and tensor tympani muscles.
8. Inferior surface of petrous temporal bone: It gives origin to the levator veli palatini.
9. Margins of the foramen magnum: It provides attachment to:
   a. Anterior atlanto-occipital membrane, anteriorly.
   b. Posterior atlanto-occipital membrane, posteriorly.
   c. Alar ligaments on the roughened medial surface of each occipital condyle.
10. Ligamentum nuchae is attached to the external occipital protuberance and crest.
11. Rectus capitis lateralis is inserted into the inferior surface of the jugular process of the occipital bone
12. Squamous part of the occipital bone: The area between the superior and inferior nuchal lines provides insertion medially to the semispinalis capitis, and laterally to the obliquus capitis superior muscle.

    The area below the inferior nuchal line provides insertion medially to the rectus capitis posterior minor, and laterally to the rectus capitis posterior major.
13. Mastoid notch gives origin to the posterior belly of digastric muscle.

The structures passing through various foramina of skull are listed in Table 1.2.

TABLE 1.2: Structures passing through foramina of skull

Foramen	***Structures***
Incisive foramen	Terminal parts of the greater palatine vessels from the palate to the nose Terminal part of the nasopalatine nerve from the nose to the palate
Greater palatine foramen	Greater palatine vessels (Fig. 1.12) Anterior palatine nerve (both of which run forwards in the groove that passes forwards from the foramen)
Lesser palatine foramina	Middle and posterior palatine nerves
Palatinovaginal canal	Pharyngeal branch from the pterygopalatine ganglion A small pharyngeal branch of the maxillary artery
Vomerovaginal canal (if patent)	Pharyngeal branch from pterygopalatine ganglion and vessels
Foramen ovale	**M**andibular nerve (Fig. 1.11) **A**ccessory meningeal artery **L**esser petrosal nerve **E**missary vein connecting the cavernous sinus with the pterygoid plexus of veins Anterior trunk of middle meningeal vein (occasionally) [*Mnemonic*—**MALE]**
Foramen spinosum	Middle meningeal artery Meningeal branch of the mandibular nerve or nervus spinosus Posterior trunk of the middle meningeal vein
Emissary sphenoidal foramen (foramen of Vesalius)	Emissary vein connecting the cavernous sinus with the pterygoid plexus of veins
Canaliculus innominatus (if present)	Lesser petrosal nerve (in place of foramen ovale)
Carotid canal	Internal carotid artery Venous and sympathetic plexuses around the artery
Foramen lacerum (Fig. 1.13)	During life, the lower part of the foramen is filled with cartilage, and no significant structure passes through the whole length of the canal, except for the meningeal branch of the ascending pharyngeal artery and an emissary vein from the cavernous sinus. However, the upper part of the foramen is traversed by the internal carotid artery with venous and sympathetic plexuses around it. In the anterior part of the foramen, the greater petrosal nerve unites with the deep petrosal nerve to form the nerve of the pterygoid canal (Vidian's nerve), which leaves the foramen by entering the pterygoid canal in the anterior wall of the foramen lacerum (Figs 1.15a and b).

(Contd.)

TABLE 1.2: Structures passing through foramina of skull *(Contd.)*

Foramen	***Structures***
Medial end of the petrotympanic fissure	Chorda tympani nerve Anterior ligament of malleus Anterior tympanic artery
Foramen magnum (Fig. 1.14, Flowchart 1.11)	Through the narrow anterior part: a. Apical ligament of dens b. Vertical band of cruciate ligament c. Membrana tectoria Through wider posterior part: a. Lowest part of medulla oblongata b. Three meninges Through the subarachnoid space pass: a. Spinal accessory nerves b. Vertebral arteries with its sympathetic plexus c. Posterior spinal arteries d. Anterior spinal artery
Hypoglossal or anterior condylar canal	Hypoglossal nerve Meningeal branch of the hypoglossal nerve (These are the sensory fibres of first cervical spinal nerve supplying the dura mater of posterior cranial fossa) Meningeal branch of the ascending pharyngeal artery Emissary vein connecting the sigmoid sinus with the internal jugular vein
Posterior condylar canal	Emissary vein connecting the sigmoid sinus with suboccipital venous plexus
Jugular foramen *Note*: The glossopharyngeal notch near the medial end of the jugular foramen lodges the inferior ganglion of the glossopharyngeal nerve (Fig. 1.15, Flowchart 1.12)	Through the anterior part: a. Inferior petrosal sinus b. Meningeal branch of the ascending pharyngeal artery Through the middle part: IX, X and XI cranial nerves Through the posterior part: a. Internal jugular vein b. Meningeal branch of the occipital artery.
Mastoid canaliculus (Arnold's canal) (lies in the lateral wall of the jugular fossa)	Auricular branch of the vagus (Arnold's nerve)
Tympanic canaliculus (on the thin edge of partition between the jugular fossa and carotid canal)	Tympanic branch of glossopharyngeal nerve (Jacobson's nerve) to the middle ear cavity
Stylomastoid foramen	Facial nerve Stylomastoid branch of the posterior auricular artery
External nasal foramen	External nasal nerve
Inferior orbital fissure	Zygomatic nerve; orbital branches of pterygopalatine ganglion; infraorbital nerve and vessels
Infraorbital foramen	Infraorbital nerve and vessels
Petrotympanic fissure	Chorda tympanic nerve, anterior ligament of malleus and anterior tympanic artery
Pterygoid canal	Nerve to pterygoid canal and vessels
Pterygomaxillary fissure	Maxillary nerve
Pterygopalatine fossa	Pterygopalatine ganglion
Supraorbital foramen	Supraorbital nerve and vessels
Zygomatic foramen	Zygomatic nerve
Zygomaticofacial foramen	Zygomaticofacial nerve
Zygomaticotemporal foramen	Zygomaticotemporal nerve

Note: Auricular branch of the vagus (Arnold's nerve) passes laterally through the bone, crosses the facial canal and emerges at the tympanomastoid fissure. The nerve is extracranial at birth, but becomes surrounded by bone as the tympanic plate and mastoid process develop (also called Alderman's nerve).

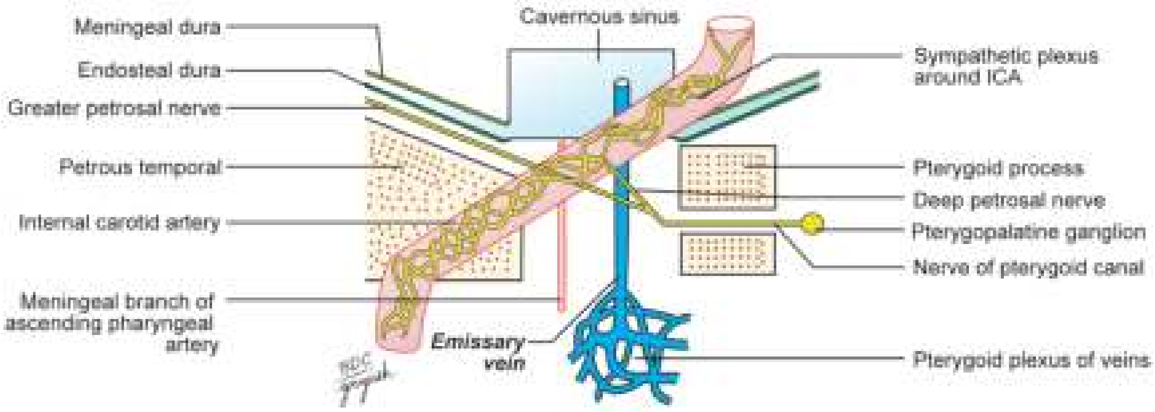

Meningeal dura
Endosteal dura
Greater petrosal nerve
Petrous temporal
Internal carotid artery
Meningeal branch of ascending pharyngeal artery
Cavernous sinus
Emissary vein
Sympathetic plexus around ICA
Pterygoid process
Deep petrosal nerve
Pterygopalatine ganglion
Nerve of pterygoid canal
Pterygoid plexus of veins

Fig. 1.13: Structures related to the foramen lacerum

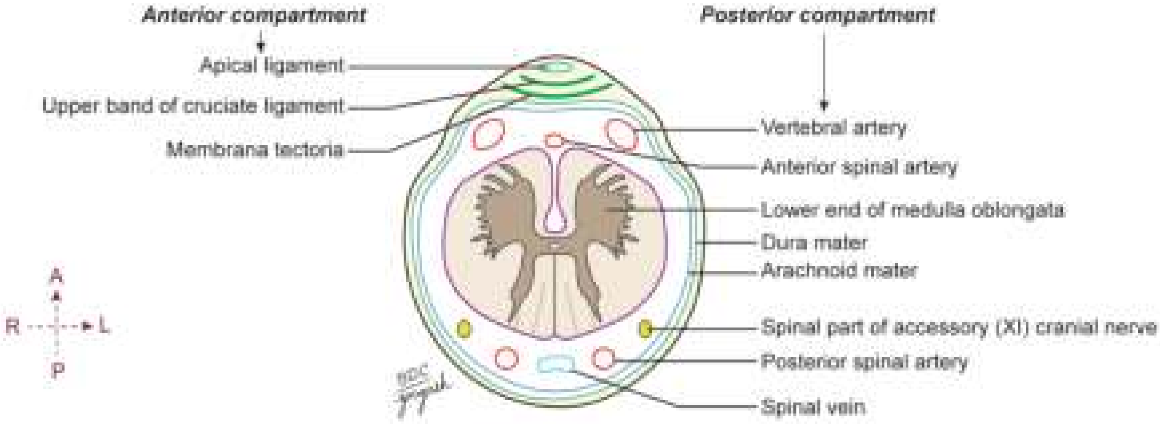
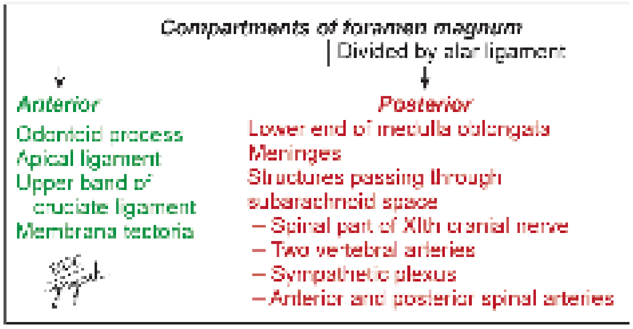

Anterior compartment
Posterior compartment
Apical ligament
Upper band of cruciate ligament
Membrana tectoria
Vertebral artery
Anterior spinal artery
Lower end of medulla oblongata
Dura mater
Arachnoid mater
Spinal part of accessory (XI) cranial nerve
Posterior spinal artery
Spinal vein
A
R
L
P

Fig. 1.14: Structures passing through foramen magnum

Flowchart 1.11: Foramen magnum


Compartments of foramen magnum
Divided by alar ligament
Anterior
Odontoid process
Apical ligament
Upper band of cruciate ligament
Membrana tectoria
Posterior
Lower end of medulla oblongata
Meninges
Structures passing through subarachnoid space
– Spinal part of XIth cranial nerve
– Two vertebral arteries
– Sympathetic plexus
– Anterior and posterior spinal arteries

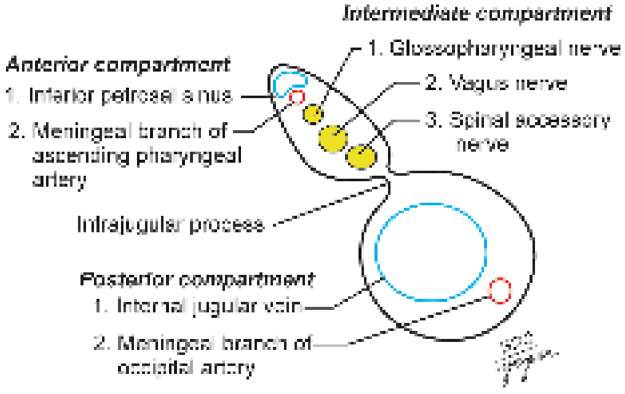
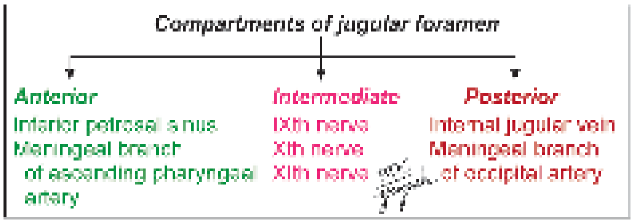

Intermediate compartment
1. Glossopharyngeal nerve
2. Vagus nerve
3. Spinal accessory nerve
Anterior compartment
1. Inferior petrosal sinus
2. Meningeal branch of ascending pharyngeal artery
Infrajugular process
Posterior compartment
1. Internal jugular vein
2. Meningeal branch of occipital artery

Fig. 1.15: Jugular foramen

Flowchart 1.12: Jugular foramen


Compartments of jugular foramen
Anterior
Inferior petrosal sinus
Meningeal branch of ascending pharyngeal artery
Intermediate
IXth nerve
Xth nerve
XIth nerve
Posterior
Internal jugular vein
Meningeal branch of occipital artery

INTERIOR OF THE SKULL

- The cranium is lined internally by ***endocranium***, which is continuous with the pericranium through the foramina and sutures (Plate 1.10, Fig. 1.16, Flowchart 1.13).
- The *thickness* of the cranial vault is variable. The bones covered with muscles, i.e. temporal and posterior cranial fossae, are thinner than those covered with scalp. Further, the bones are thinner in females than in males, and in children than in adults.
- Most of the cranial bones consist of:
  a. An *outer table* of compact bone, which is thick, resilient and tough.
  b. An *inner table* of compact bone, which is thin and brittle.
  c. The *diploe* that consists of spongy bone filled with red marrow, in between the two tables.

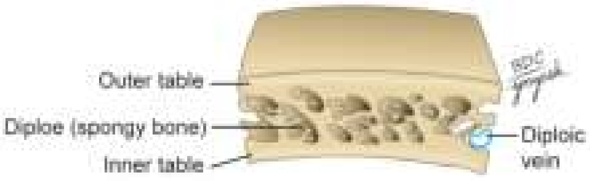


Fig. 1.16: Structure of cranial bones

Note: The skull bones derive their blood supply mostly from the meningeal arteries from inside and very little from the arteries of the scalp. Blood supply from the outside is rich in those areas where muscles are attached, e.g. the temporal fossa and the suboccipital region. The blood from the diploes is drained by four diploic veins on each side draining into venous sinuses (Table 1.3 and Fig. 1.17).

Many bones, like vomer (Latin *ploughshare*), pterygoid plates, do not have any diploe.

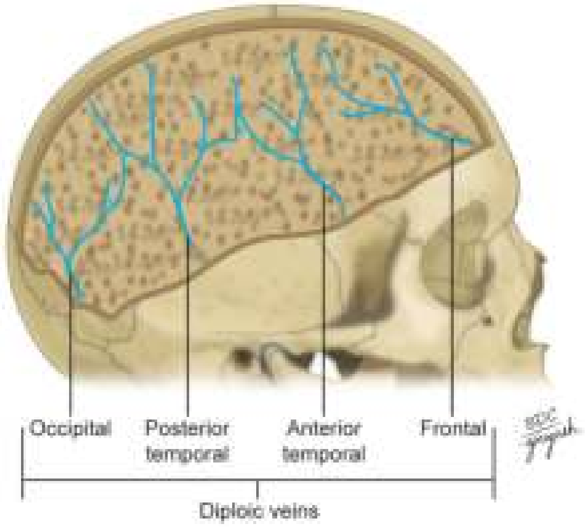


Fig. 1.17: Diploic veins

INTERNAL SURFACE OF CRANIAL VAULT

The shape, the bones present and the sutures uniting them have been described with the norma verticalis. It shows the following features (Plate 1.9):

1. The *inner table* is thin and brittle. It presents *markings* produced by meningeal vessels, venous sinuses, arachnoid granulations and to some extent by cerebral gyri. It also presents raised ridges formed by the attachments of the dural folds.
2. The ***frontal crest*** lies anteriorly in the median plane. It projects backwards.
3. The ***sagittal sulcus*** runs from before backwards in the median plane. It becomes progressively wider posteriorly. It lodges the superior sagittal sinus.
4. The ***granular foveolae*** are deep, irregular, large, pits situated on each side of the sagittal sulcus. They are formed by arachnoid granulations. They are larger and more numerous in aged persons.
5. ***Vascular markings:*** The groove for the anterior branch of the middle meningeal artery, and the accompanying vein runs upwards 1 cm behind the coronal suture. Smaller grooves for the branches from the anterior and posterior branches of the middle meningeal vessels run upwards and backwards over the parietal bone.
6. The ***parietal foramina*** open near the sagittal sulcus 2.5 to 3.75 cm in front of the lambdoid suture.
7. The *impressions for cerebral gyri* are less distinct. These become very prominent in cases of raised intracranial tension.

Competencies:

AN26.3 Describe cranial cavity, its subdivisions, foramina and structures passing through them.

AN30.1 Describe the cranial fossae and identify related structures.

INTERNAL SURFACE OF THE BASE OF SKULL

The interior of the base of skull presents natural subdivisions into the anterior, middle and posterior cranial fossae. The dura mater is firmly adherent to the floor of fossae and is continuous with pericranium through the foramina and fissures (Plate 1.10, Fig. 1.18, Flowchart 1.13).

Anterior Cranial Fossa

It is separated from the middle cranial fossa by the free *posterior border* of the *lesser wing of the sphenoid*, the *anterior clinoid process* and the *anterior margin of the sulcus chiasmaticus* (Plate 1.11).

Floor

It is formed by:

1. *Cribriform plate of the ethmoid bone*
2. *Body of the sphenoid or jugum sphenoidale*
3. *Orbital plate of the frontal bone*
4. *Lesser wing of the sphenoid.*

TABLE 1.3: Diploic veins

Vein	*Foramen*	*Drainage*
Frontal diploic vein	Supraorbital foramen	Drain into supraorbital vein
Anterior temporal or parietal diploic vein	In the greater wing of sphenoid	Sphenoparietal sinus or in anterior deep temporal vein
Posterior temporal or parietal diploic vein	Mastoid foramen	Transverse sinus
Occipital diploic vein (largest)	Foramen in occipital bone	Occipital vein or confluence of sinuses
Small unnamed diploic veins	Pierce inner table of skull close to the margins of superior sagittal sinus	Venous lacunae

Plate 1.9: Internal surface of the vault of the skull (calvaria or skull cap)

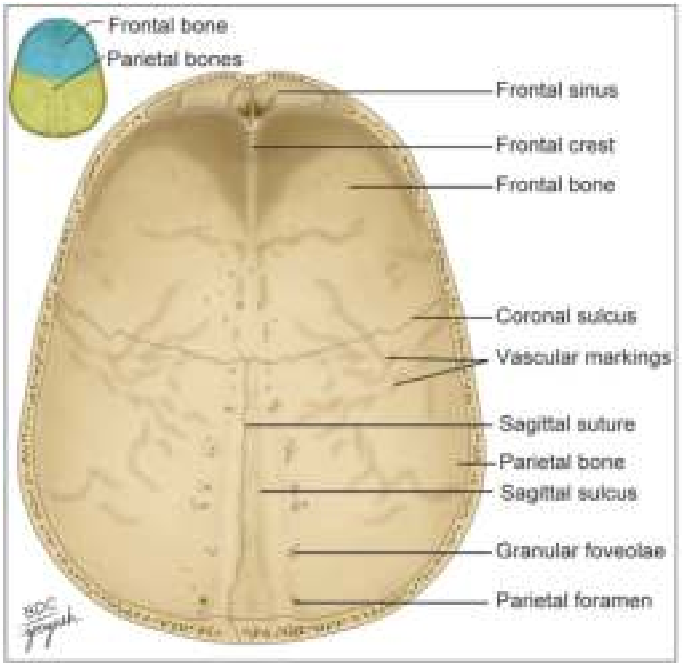
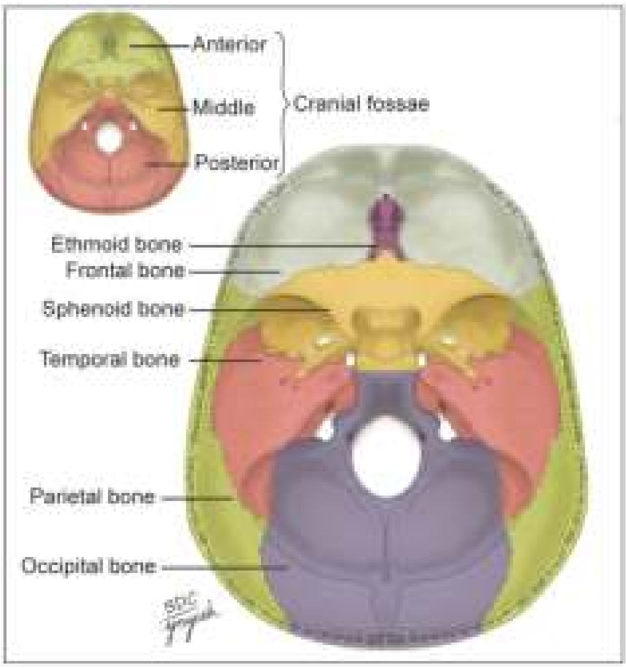

Frontal bone
Parietal bones
Frontal sinus
Frontal crest
Frontal bone
Coronal sulcus
Vascular markings
Sagittal suture
Parietal bone
Sagittal sulcus
Granular foveolae
Parietal foramen

Plate 1.10: Cranial fossae and bones forming the interior of the skull


Anterior
Middle
Posterior
Cranial fossae
Ethmoid bone
Frontal bone
Sphenoid bone
Temporal bone
Parietal bone
Occipital bone

Flowchart 1.13: Features of interior of the base of skull

Anterior cranial fossa

Features

- Frontal crest
  - Falx cerebri
- Crista galli
  - Falx cerebri
- Jugum sphenoidale
- Cribriform plate of ethmoid
- Orbital plate of frontal bone
- Lesser wing of sphenoid
  - Free posterior border
  - Anterior clinoid process
  Free margin of tentorium cerebelli

Foramina

- Foramen caecum
  - Emissary vein
- Anterior ethmoidal canal
  - Anterior ethmoidal nerve and vessels
- Posterior ethmoidal canal
  - Posterior ethmoidal nerve and vessels
- Optic canal
  - Optic nerve
  - Ophthalmic artery

Superior orbital fissure

Lies between the greater and lesser wings of sphenoid bone
Divided into 3 parts by tendinous ring

Lateral part

- Lacrimal nerve
- Frontal nerve
- Trochlear nerve
- Superior ophthalmic vein

Middle part

- Upper and lower divisions of oculomotor nerve
- Nasociliary nerve
- Abducent nerve

Medial part

- Inferior ophthalmic vein
- Sympathetic nerves

Median area of middle cranial fossa

Body of sphenoid

Features

- Sulcus chiasmaticus
- Sella turcica
  - Occupies pituitary gland
  - Tuberculum sellae
  - Middle clinoid process
  - Dorsum sellae
  - Posterior clinoid process
- Carotid groove

Attachments

- Posterior clinoid process
- Tuberculum sellae and dorsum sellae
  - Diaphragma sellae

Foramen

- Optic canal
  - Optic nerve
  - Ophthalmic artery
- Carotid groove
  - Internal carotid artery

Lateral area of middle cranial fossa

Features

- Greater wing of sphenoid
- Groove for middle meningeal vessels
- Trigeminal impression
- Hiatus for greater and lesser petrosal nerves
- Arcuate eminence
- Tegmen tympani

Foramina

- Foramen spinosum: Middle meningeal artery, nervous spinosus
- Foramen ovale: Mandibular nerve, accessory meningeal artery, lesser petrosal nerve, emissary vein
- Foramen rotundum: Maxillary nerve
- Foramen lacerum: Emissary vein
- Superior orbital fissure

Median area of posterior cranial fossa

Features

- Clivus
- Foramen magnum
- Internal occipital protuberance
- Internal occipital crest
- Vermian fossa
- Groove for transverse sinus
- Cerebellar fossa

Relations and foramina

- Clivus: Related to pons, medulla, basilar venous plexus
- Attachments
  1. Apical ligament of dens
  2. Vertical band of cruciate ligament
  3. Membrana tectoria
- Internal occipital crest
  1. Falx cerebelli
- Foramen magnum

Lateral area of posterior cranial fossa

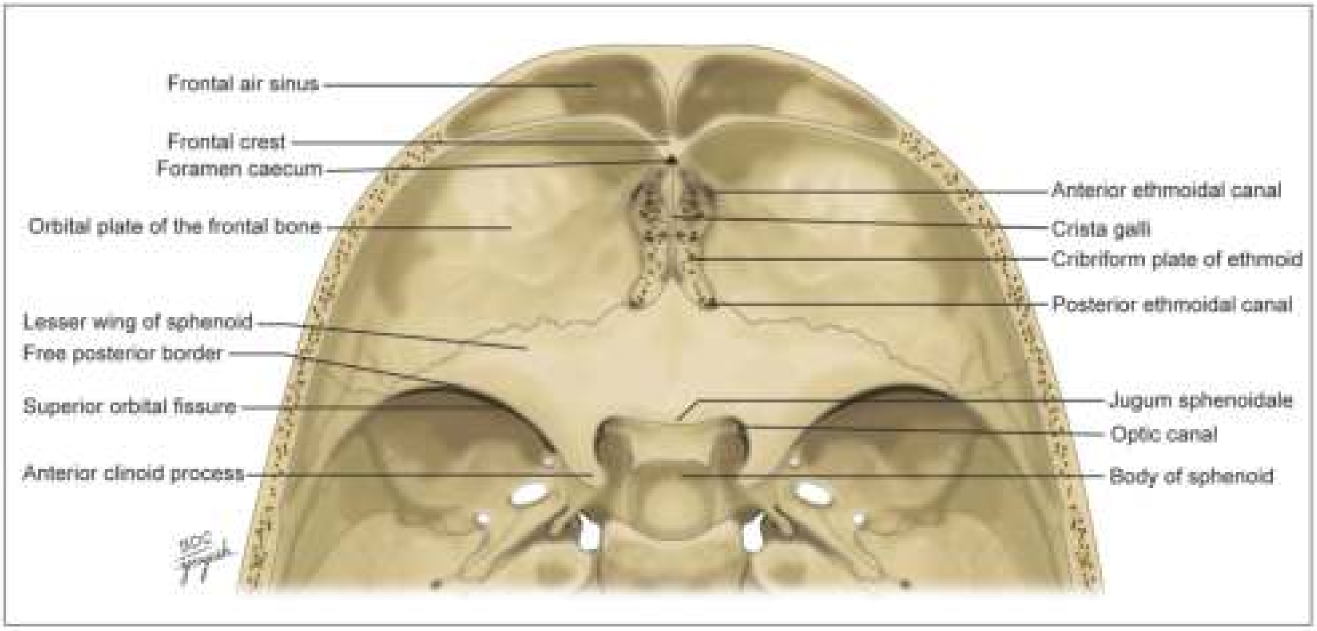
Features

- Condylar part of occipital bone
  - Jugular tubercle
- Posterior surface of petrous part of temporal bone
- Mastoid part of temporal bone
  - Sigmoid sulcus

Foramina

- Hypoglossal canal
  - 12th nerve
  - Meningeal branch of ascending pharyngeal artery
  - Emissary vein
- Condylar canal: Emissary vein
- Internal acoustic meatus
  - VII and VIII nerves
  - Labyrinthine vessels
- Jugular foramen
- Mastoid foramen: Emissary vein

Plate 1.11: Features of anterior cranial fossa


Frontal air sinus
Frontal crest
Foramen caecum
Orbital plate of the frontal bone
Lesser wing of sphenoid
Free posterior border
Superior orbital fissure
Anterior clinoid process
Anterior ethmoidal canal
Crista galli
Cribriform plate of ethmoid
Posterior ethmoidal canal
Jugum sphenoidale
Optic canal
Body of sphenoid

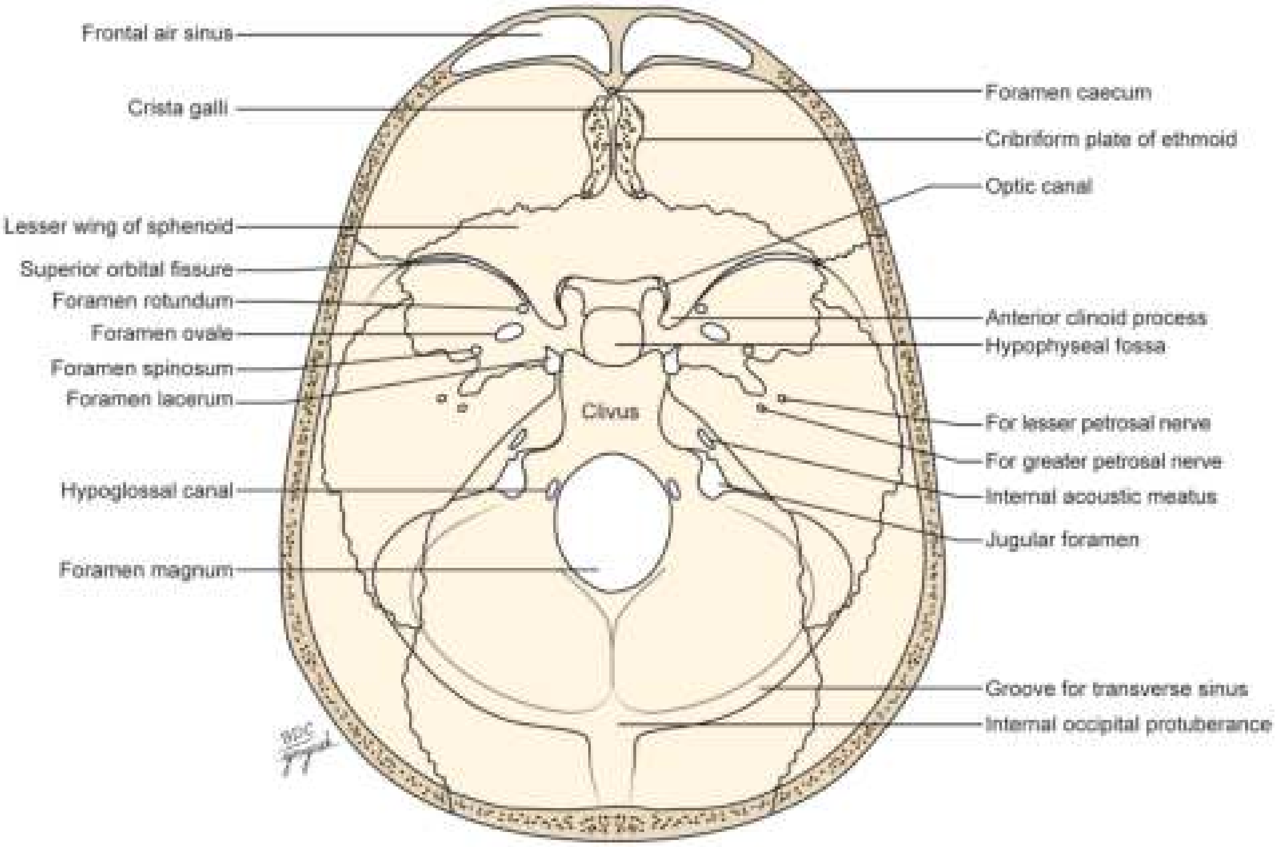

Frontal air sinus
Crista galli
Lesser wing of sphenoid
Superior orbital fissure
Foramen rotundum
Foramen ovale
Foramen spinosum
Foramen lacerum
Hypoglossal canal
Foramen magnum
Foramen caecum
Cribriform plate of ethmoid
Optic canal
Anterior clinoid process
Hypophyseal fossa
Clivus
For lesser petrosal nerve
For greater petrosal nerve
Internal acoustic meatus
Jugular foramen
Groove for transverse sinus
Internal occipital protuberance

Fig. 1.18: Features of cranial fossae

Features

1. ***Cribriform plate of the ethmoid bone*** separates the anterior cranial fossa from the nasal cavity. It is quadrilateral in shape.
    a. *Anterior* margin articulates with the frontal bone at the *frontoethmoidal suture*, which is marked in the median plane by the ***foramen caecum***. This foramen is usually blind, but is occasionally patent.
    b. *Posterior margin* articulates with the jugum sphenoidale. At the posterolateral corners of cribriform plane, one sees the ***posterior ethmoidal canals***.

c. Its *lateral margins* articulate with the orbital plate of the frontal bone: The suture between them presents the ***anterior ethmoidal canal*** placed behind the crista galli.

Anteriorly, the cribriform plate has a midline projection called the ***crista galli*** (Latin *cock's comb*). On each side of the crista galli, there are foramina through which the *anterior ethmoidal nerve and vessels* pass to the nasal cavity. The plate is also perforated by *numerous foramina* for the passage of olfactory nerve rootlets.

2. ***Jugum sphenoidale*** separates the anterior cranial fossa from the sphenoidal sinuses.
3. ***Orbital plate of the frontal bone*** separates the anterior cranial fossa from the orbit. It supports the orbital surface of the frontal lobe of the brain, and presents reciprocal impressions. The *frontal air sinus* may extend into its anteromedial part.
4. ***Lesser wing of the sphenoid*** is broad medially where it is continuous with the jugum sphenoidale and tapers laterally. The free *posterior border* fits into the *stem of the lateral sulcus of the brain*. It ends medially as a prominent projection, the ***anterior clinoid process***. Inferiorly, the posterior border forms the upper boundary of the *superior orbital fissure*. Medially, the lesser wing is connected to the body of the sphenoid by ***anterior and posterior roots***, which enclose the ***optic canal***.

CLINICAL ANATOMY

Fracture of the anterior cranial fossa may cause bleeding and discharge of cerebrospinal fluid through the nose. It may also cause a condition called *black eye*, which is produced by seepage of blood into the eyelid, as frontalis muscle has no bony origin.

Middle Cranial Fossa

It is deeper than the anterior cranial fossa, and is shaped like a butterfly, being narrow and shallow in the middle; and wide and deep on each side. It is separated from the posterior cranial fossa by the superior border of the petrous temporal bone, and the dorsum sellae of the sphenoid (Plate 1.12).

Floor

Floor is formed by body of sphenoid in the median region and by greater wing of sphenoid, squamous temporal and anterior surface of petrous temporal on each side.

Features

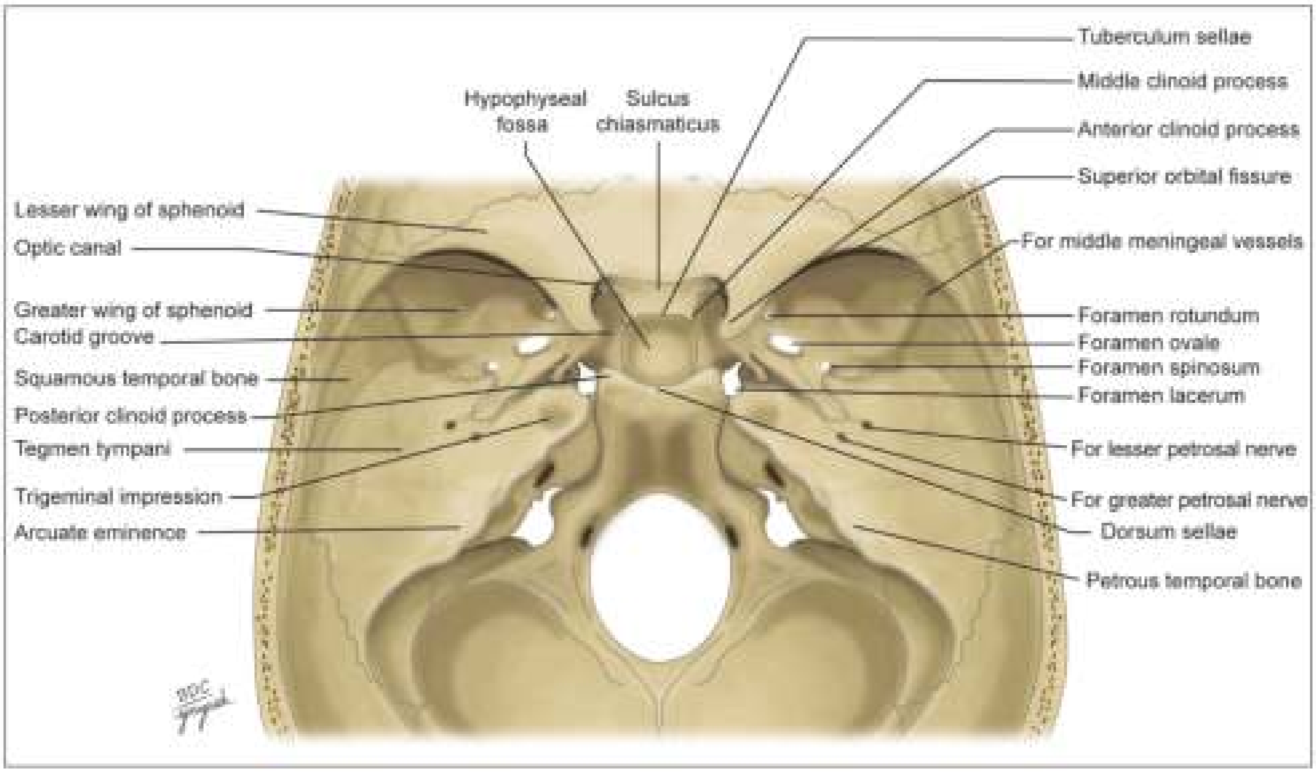
Median area: The body of the sphenoid presents the following features:

1. ***Sulcus chiasmaticus*** or *optic groove* leads, on each side, to the optic canal. The optic chiasma does not occupy the sulcus, it lies at a higher level well behind the sulcus.
2. ***Optic canal*** leads to the orbit. It is bounded laterally by the lesser wing of the sphenoid, in front and behind by the two roots of the lesser wing, and medially by the body of sphenoid.
3. ***Sella turcica*** (pituitary fossa or hypophyseal fossa): The upper surface of the body of the sphenoid is hollowed out in the form of a Turkish saddle, and is known as the *sella turcica*. It consists of the *tuberculum sellae* in front, the *hypophyseal fossa* in the middle and the *dorsum sellae* behind.
4. ***Tuberculum sellae*** separates the optic groove from the *hypophyseal fossa*. Its lateral ends form the *middle clinoid process*, which may join the anterior clinoid process.
5. ***Hypophyseal fossa*** lodges the hypophysis cerebri. Beneath the floor of fossa lie the sphenoidal air sinuses.
6. ***Dorsum sellae*** is a transverse plate of bone projecting upwards; it forms the back of the saddle. The superolateral angles of the dorsum sellae are expanded to form the *posterior clinoid processes*.

Lateral area

1. The lateral area is deep and lodges the temporal lobe of the brain.
2. ***Superior orbital fissure*** opens anteriorly into the orbit. It is *bounded* above by the lesser wing, below by the greater wing, and medially by the body of the sphenoid. Its medial end is wider than the lateral. The long axis of the fissure is directed laterally, upwards and forwards. The lower border is marked by a small projection, which provides attachment to the *common tendinous ring of Zinn*. The ring divides the fissure into three parts.
3. ***Greater wing of the sphenoid*** presents the following features:
    a. ***Foramen rotundum*** leads anteriorly to the pterygopalatine fossa containing pterygopalatine ganglia.
    b. ***Foramen ovale*** lies posterolateral to the foramen rotundum and lateral to the lingula. It leads inferiorly to the infratemporal fossa.
    c. ***Foramen spinosum*** lies posterolateral to the foramen ovale. It also leads, inferiorly, to the infratemporal fossa.
    d. ***Emissary sphenoidal foramen*** or foramen of Vesalius carries an emissary vein.
4. ***Foramen lacerum*** lies at the posterior end of the carotid groove, posteromedial to the foramen ovale.
5. ***Anterior surface of the petrous temporal bone*** presents the following features:
    a. *Trigeminal impression* lies near the apex, behind the foramen lacerum. It lodges the trigeminal ganglion within its dural cave.
    b. *Hiatus and groove for the greater petrosal nerve* are present lateral to the trigeminal impression. They lead to the foramen lacerum.
    c. *Hiatus* and *groove for the lesser petrosal nerve* lie lateral to the hiatus for the greater petrosal nerve. They lead to the foramen ovale or to canaliculus innominatus to relay in otic ganglion.

Plate 1.12: Features of middle cranial fossa


Hypophyseal fossa
Sulcus chiasmaticus
Tuberculum sellae
Middle clinoid process
Anterior clinoid process
Superior orbital fissure
For middle meningeal vessels
Lesser wing of sphenoid
Optic canal
Greater wing of sphenoid
Carotid groove
Squamous temporal bone
Posterior clinoid process
Tegmen tympani
Trigeminal impression
Arcuate eminence
Foramen rotundum
Foramen ovale
Foramen spinosum
Foramen lacerum
For lesser petrosal nerve
For greater petrosal nerve
Dorsum sellae
Petrous temporal bone

d. Still more laterally there is the *arcuate eminence* produced by the superior semicircular canal.

e. ***Tegmen tympani*** is a thin plate of bone anterolateral to the arcuate eminence. It forms a continuous sloping roof for the tympanic antrum, for the tympanic cavity and for the canal for the tensor tympani. The lateral margin of the tegmen tympani is turned downwards; it forms the lateral wall of the bony auditory tube. Its lower edge is seen in the squamotympanic fissure and divides it into the petrosquamous and petrotympanic fissures.

6. ***Cerebral surface of the squamous temporal bone*** is concave. It shows impressions for the temporal lobe and grooves for branches of the middle meningeal vessels.

CLINICAL ANATOMY

Fracture of the middle cranial fossa produces:

a. Bleeding and discharge of CSF through the ear.
b. Bleeding through the nose or mouth may occur due to involvement of the sphenoid bone.
c. The seventh and eighth cranial nerves may be damaged, if the fracture also passes through the internal acoustic meatus. If a semicircular canal is damaged, vertigo may occur.

Posterior Cranial Fossa

This is the largest and deepest of the three cranial fossae. The posterior cranial fossa contains the *hindbrain*, which consists of the *cerebellum behind and the pons and medulla in front* (Plate 1.13).

Floor

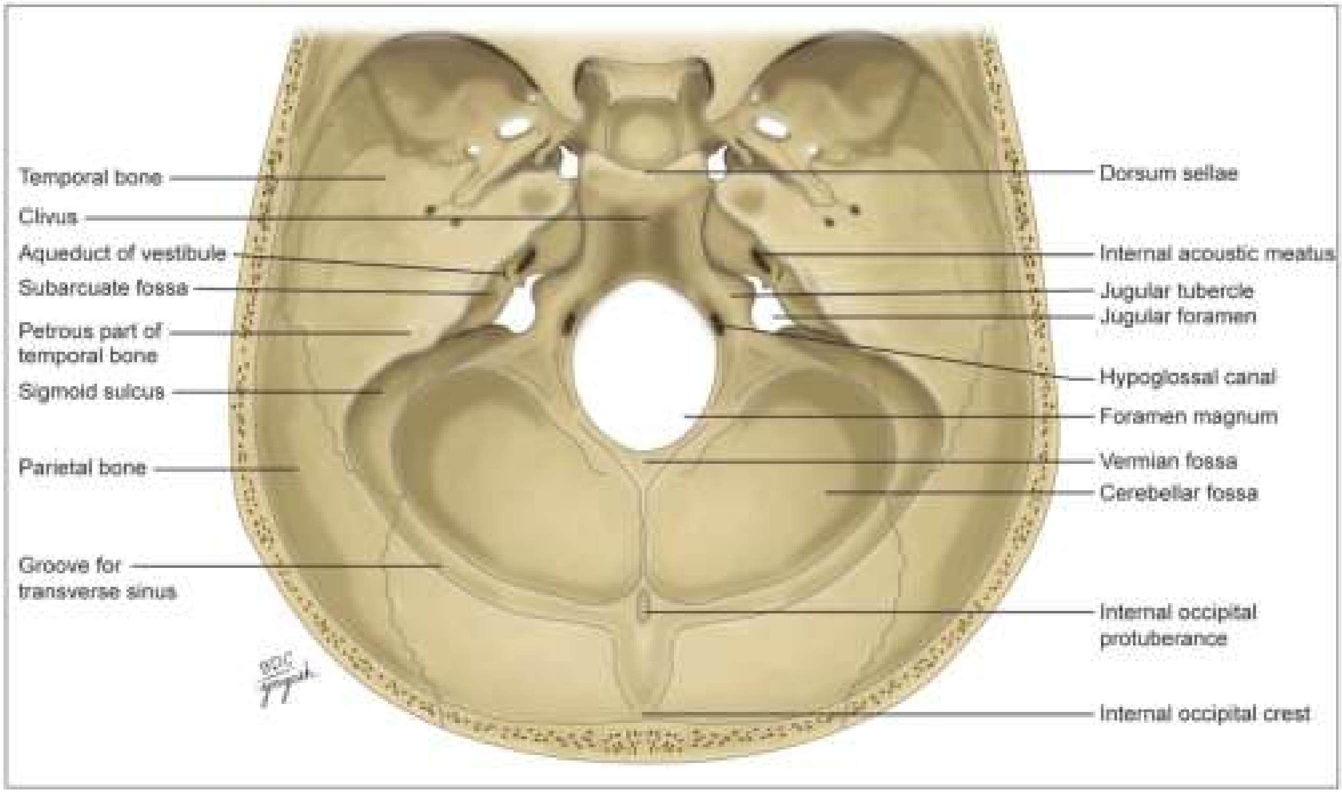
It is formed by clivus, foramen magnum and part of temporal and occipital bones.

Features

Median area

1. ***Clivus*** is the sloping surface in front of the foramen magnum. It is formed by fusion of the posterior part of the body of the sphenoid, including the dorsum sellae with the basilar part of the occipital bone or basiocciput. It is related to the *basilar plexus of veins*, and supports the pons and medulla.
2. On each side, the clivus is separated from the petrous temporal bone by the *petro-occipital fissure*, which is grooved by the inferior petrosal sinus, and is continuous behind with the jugular foramen.
3. ***Foramen magnum*** lies in the floor of the fossa. The anterior part of the foramen is narrow because it is *overlapped* by the medial surfaces of the occipital condyles.
4. ***Squamous part of the occipital bone*** shows the following features:
    a. ***Internal occipital protuberance*** lies opposite the external occipital protuberance. It is related to the confluence of sinuses, and is grooved on each side by the beginning of transverse sinuses.
    b. ***Internal occipital crest*** runs in the median plane from the internal occipital protuberance to the

Plate 1.13: Features of the posterior cranial fossa


Temporal bone
Clivus
Aqueduct of vestibule
Subarcuate fossa
Petrous part of temporal bone
Sigmoid sulcus
Parietal bone
Groove for transverse sinus
Dorsum sellae
Internal acoustic meatus
Jugular tubercle
Jugular foramen
Hypoglossal canal
Foramen magnum
Vermian fossa
Cerebellar fossa
Internal occipital protuberance
Internal occipital crest

foramen magnum where it forms a shallow depression, the *vermian fossa.*

c. ***Transverse sulcus*** is quite wide and runs laterally from the internal occipital protuberance to the mastoid angle of the parietal bone where it becomes continuous with the sigmoid sulcus. The transverse sulcus lodges the *transverse sinus.* The right transverse sulcus is usually wider than the left and is continuous medially with the superior sagittal sulcus.

d. On each side of the internal occipital crest, there are *deep fossae*, which lodge the cerebellar hemispheres.

Lateral area

1. ***Condylar part of the occipital bone*** is marked by the following features:
   a. ***Jugular tubercle*** lies over the occipital condyle.
   b. ***Hypoglossal canal*** (anterior condylar canal) pierces the bone posteroanterior to the jugular tubercle and runs obliquely forwards and laterally along the line of fusion between the basilar and the condylar parts of the occipital bone.
   c. *Condylar canal* (posterior condylar canal) opens in the lower part of the sigmoid sulcus, which indents the jugular process of occipital bone.
2. ***Posterior surface of the petrous part of the temporal bone*** forms the anterolateral wall of the posterior cranial fossa. The following features may be noted:
   a. ***Internal acoustic meatus*** opens above the anterior part of the jugular foramen. It is about 1 cm long and runs transversely in a lateral direction. It is closed laterally by a perforated plate of bone known as *lamina cribrosa*, which separates it from the internal ear.
   b. The orifice of the *aqueduct of the vestibule* is a narrow slit lying behind the internal acoustic meatus.
   c. The *subarcuate fossa* lies below the arcuate eminence, lateral to the internal acoustic meatus. It lodges the flocculus of the cerebellum.
3. ***Jugular foramen*** lies at the posterior end of the petro-occipital fissure. The upper margin is sharp and irregular, and presents the *glossopharyngeal notch*. The lower margin is smooth and regular.
4. *Mastoid part of the temporal bone* forms the lateral wall of the posterior cranial fossa just behind the petrous part of the bone. Anteriorly, it is marked by the *sigmoid sulcus*, which begins as a downward continuation of the transverse sulcus at the mastoid angle of the parietal bone, and ends at the jugular foramen. The sigmoid sulcus lodges the *sigmoid sinus*, which become the internal jugular vein at the jugular foramen. The sulcus is related anteriorly to the *tympanic antrum.* The *mastoid foramen* opens into the upper part of the sulcus.

CLINICAL ANATOMY

Fracture of the posterior cranial fossa causes bruising over the mastoid region extending down over the sternocleidomastoid muscle.

ATTACHMENTS AND RELATIONS: INTERIOR OF THE SKULL

Attachment on Vault

1. The frontal crest gives attachment to the falx cerebri.
2. The lips of the sagittal sulcus give attachment to the falx cerebri.

Anterior Cranial Fossa

1. The crista galli gives attachment to the falx cerebri.
2. The orbital surface of the frontal bone supports the frontal lobe of the brain.
3. The anterior clinoid processes give attachment to the free margin of the tentorium cerebelli.

Middle Cranial Fossa

1. The middle cranial fossa lodges the *temporal lobe of the cerebral hemisphere.*
2. The tuberculum sellae provides attachment to the *diaphragma sellae*
3. The hypophyseal fossa lodges the *hypophysis cerebri.*
4. Upper margin of the dorsum sellae provides attachment to the diaphragma sellae, and the posterior clinoid process to anterior end of the attached margin of tentorium cerebelli
5. One *cavernous sinus* lies on each side of the body of the sphenoid. The internal carotid artery passes through the cavernous sinus.
6. The superior border of the petrous temporal bone is grooved by the *superior petrosal sinus* and provides attachment to the *attached margin of the tentorium cerebelli*. It is grooved in its medial part by the *trigeminal nerve* (trigeminal impression).

Posterior Cranial Fossa

1. The posterior cranial fossa contains the hindbrain, which consists of the cerebellum behind, and the pons and medulla in front (Plate 1.13).
2. The lower part of the clivus provides attachment from above downwards to: Membrana tectoria, upper vertical band of cruciate ligament and apical ligament (MCA).
3. The internal occipital crest gives attachment to the falx cerebelli.
4. The jugular tubercle is grooved by the *ninth*, *tenth and eleventh cranial nerves* as they pass to the jugular foramen.
5. The subarcuate fossa on the posterior surface of petrous temporal bone lodges the *flocculus of the cerebellum*.

Competency:
AN30.2 Describe and identify major foramina with structures passing through them.

Structures Passing Through Foramina

The following foramina seen in the cranial fossae have been dealt with under the norma basalis: Foramen ovale, foramen spinosum, emissary sphenoidal foramen, foramen lacerum, foramen magnum, jugular foramen, hypoglossal canal and posterior condylar canal. Additional foramina seen in the cranial fossae are listed in Table 1.4.

TABLE 1.4: Additional foramina seen in the cranial fossae and structures passing through them

Foramen	***Structures***
Foramen caecum	Usually blind, but occasionally it transmits emissary vein to superior sagittal sinus from upper part of nose
Posterior ethmoidal canal	Vessels of the same name. Note that the posterior ethmoidal nerve does not pass through the canal
Anterior ethmoidal canal	Corresponding nerve and vessels
Foramina of cribriform plate	Olfactory nerve rootlets
Optic canal (Fig. 1.19)	Optic nerve Ophthalmic artery
Superior orbital fissure (Fig. 1.19)	Lateral part 1. Lacrimal nerve 2. Frontal nerve 3. Trochlear nerve 4. Superior ophthalmic vein Middle part 1. Upper and lower divisions of the oculomotor nerve 2. Nasociliary nerve in between the two divisions of the oculomotor 3. The abducent nerve, inferolateral to the foregoing nerves Medial part 1. Inferior ophthalmic vein 2. Sympathetic nerves from the plexus around the internal carotid artery
Foramen rotundum	Maxillary nerve
Internal acoustic meatus	Seventh and eighth cranial nerves Labyrinthine vessels
External opening of vestibular aqueduct	Endolymphatic duct

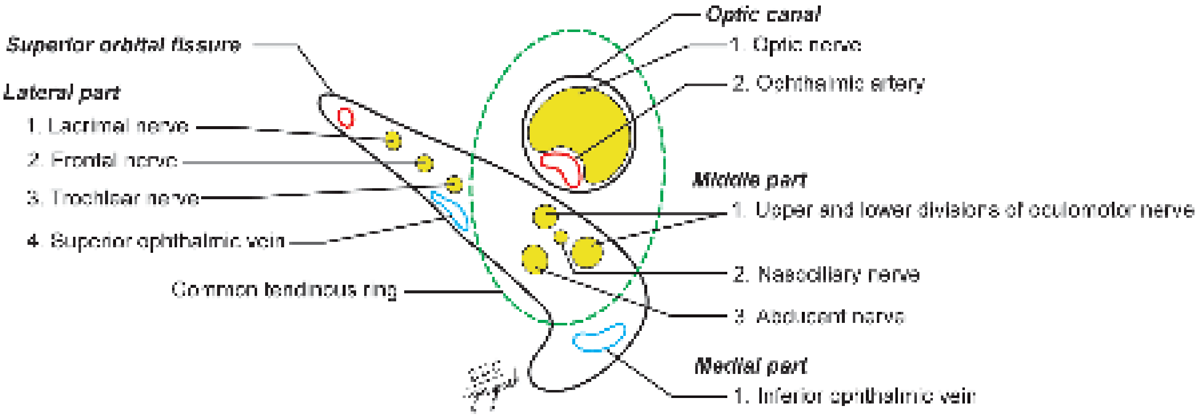


Fig. 1.19: Superior orbital fissure and optic canal

FOETAL SKULL/NEONATAL SKULL

Features of Foetal of Newborn Skull (Fig. 1.20)

1. The foetal or newborn skull is large in proportion to the other parts of skeleton.
2. *Facial skeleton* is small as compared to calvaria. In foetal skull, the facial skeleton is 1/7th of calvaria; in adults, it is half of calvaria.

   Anatomical justification: The facial skeleton is small due to rudimentary mandible and maxillae, non-eruption of teeth and small size of maxillary sinus and nasal cavity. The large size of calvaria is due to precocious growth of brain.
3. *Base of the skull* is short and narrow, though internal ear is almost of adult size, the petrous temporal has not reached the adult length.
4. *Structure of bones*: The bones of cranial vault are smooth and unilamellar; there is no diploe. The tables and diploes appear by 4th year of age.
5. *Bony prominences*
   - Frontal and parietal tubera are prominent.
   - Glabella, superciliary arches and mastoid processes are not developed.
6. *Paranasal air sinuses:* These are rudimentary or absent.
7. *Temporal bone*
   - The internal ear, tympanic cavity, tympanic antrum and ear ossicles are of adult size.
   - The tympanic part is represented by an incomplete tympanic ring.
   - Mastoid process is absent, it appears during the later part of second year.
   - External acoustic meatus is short and straight. Its bony part is unossified and represented by a fibrocartilaginous plate.
   - Tympanic membrane faces more downwards than laterally due to the absence of mastoid process.
   - Stylomastoid foramen is exposed on the lateral surface of the skull because mastoid portion is flat.
   - Styloid process lies immediately behind the tympanic ring and has not fused with the remainder of the temporal bone.
   - Mandibular fossa is flat and placed more laterally, and the anterior root/articular tubercle has not developed.
   - The subarcuate fossa is very deep and prominent.
   - Facial canal is short.
8. *Orbits:* These are large. The germs of developing teeth lies close to the orbital floor. Orbit comprises base or an outer opening with upper, lower, medial and lateral walls. Its apex lies at the optic foramen/canal. It also has superior and inferior orbital fissures.

OSSIFICATION

- Two halves of frontal bone are separated by metopic suture.
- The mandible is also present in two halves. It is a derivative of 1st branchial arch.
- Occipital bone is in four parts (squamous one, condylar two and basilar one).
- The four bony elements of temporal bone are separate, except for the commencing union of the tympanic part with the squamous and petrous parts. The second centre for styloid process has not appeared.
- Unossified membranous gaps, a total of 6 fontanelles at the angles of the parietal bones are present.
- Squamous suture between parietal and squamous temporal bones is present.

POSTNATAL GROWTH OF SKULL

The growth of calvaria and facial skeleton proceeds at different rates and over different periods. Growth of calvaria is related to growth of brain, whereas that of the facial skeleton is related to the development of dentition, muscles of mastication and of the tongue. The rates of growth of the base and vault are also different.

Growth of the Vault

1. *Rate:* Rapid during 1st year, and then it slows up to the 7th year when it is almost of adult size.
2. *Growth in breadth:* This growth occurs at the sagittal suture, sutures bordering greater wings, occipitomastoid suture, and the petro-occipital suture at the base.

3. *Growth in height*: This growth occurs at the frontozygomatic suture, pterion, squamosal suture and asterion.
4. *Growth in anteroposterior diameter:* This growth occurs at the coronal and lambdoid sutures.

Growth of the Base

The base grows in anteroposterior diameter at three cartilaginous plates situated between the occipital and sphenoid bones, between the pre- and post-sphenoids, and between the sphenoid and ethmoid.

Growth of the Face

1. Growth of orbits and ethmoid is completed by 7th year.
2. In the face, the growth occurs mostly during first year, although it continues till puberty and even later.

Thickening of Bones

1. Two tables and diploe appear by 4th year. Differentiation reaches maximum by about 35 years, when the diploic veins produce characteristic marking in the radiographs.
2. Mastoid process appears during 2nd year, and the mastoid air cells during 6th year.

Obliteration of Sutures of the Vault

1. Obliteration begins on the inner surface between 30 and 40 years, and on the outer surface between 40 and 50 years.
2. The timings are variable, but it usually takes place first in the lower part of the coronal suture, next in the posterior part of the sagittal suture and then in the lambdoid suture.
3. Obliteration of suture and age

• Sagittal suture:	35 years
• Coronal suture:	38–41 years
• Vomero-ethmoid suture:	45 years
• Lambdoid suture:	Before 50 years
• Sphenoparietal and sphenofrontal suture:	65 years
• Temporosphenoid suture:	70 years

In Old Age

The skull generally becomes thinner and lighter but in small proportion of cases, it increases in thickness and weight. The most striking feature is reduction in the size of mandible and maxillae due to loss of teeth and absorption of alveolar processes. This causes decrease in the vertical height of the face and a change in the angles of the mandible, which become more obtuse.

Closure of Fontanelles

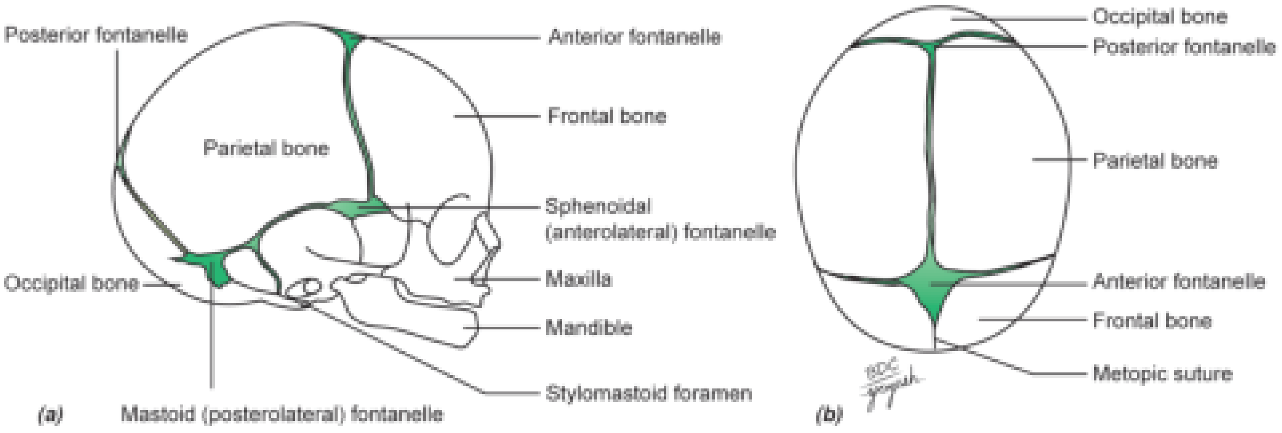
Anterior fontanelle (bregma) closes by 18 months, mastoid fontanelle by 12 months, posterior fontanelle (lambda) by 2–3 months and sphenoidal fontanelle also by 2–3 months.

Note: ***Wormian or sutural bones:*** These are small irregular bones found in the region of the fontanelles, and are formed by additional ossification centres. They are most common at the lambda and at the asterion; common at the pterion (epipteric bone); and rare at the bregma (Os Kerckring). Wormian bones are common in hydrocephalic skulls.

CLINICAL ANATOMY

Fontanelles

- Fontanelles are soft membranous gaps present in the skull vault of newborn.
- There are 6 fontanelles at birth as follows (Figs 1.20a and b):
- *Anterior fontanelle* between frontal and parietal bones. Anterior fontanelle is the largest fontanelle. It lies at the bregma.
- *Posterior fontanelle* between occipital and parietal bones. It lies at the lambda.
- *Anterolateral (sphenoid) fontanelle* between greater wing of sphenoid, squamous temporal, frontal and parietal bones. It lies at the pterion.
- *Posterolateral (mastoid) fontanelle* between parietal, occipital, squamous temporal and occipital bones. It lies at the asterion.
- *Closure of fontanelle*
  - Anterolateral, posterolateral and posterior fontanelles close within 3–4 months after birth.
  - Anterior fontanelle closes by 2–3 years of age.



Figs 1.20a and b: Fontanelles of skull: (a) Lateral aspect and (b) superior aspect

- *Function of fontanelles*
  - – Allow moulding of skull during the birth passage of body.
  - – Permit growth of skull bones to increase the cranial capacity.
  - – Accommodate developing brain.
- *Clinical aspects*
  1. Closure of fontanelles gives an idea about the age of the newborn.
  2. The anterior fontanelle is largest and of great clinical significance. Appearance of anterior fontanelle gives an idea of intracranial pressure.
     - – Bulging fontanelles indicate increased intracranial pressure.
     - – Depressed fontanelles indicate dehydration cases.
  3. If fontanelles fuse early, brain growth is stunted; such children are less intelligent.
  4. Bones override at the fontanelle helping to decrease size of head during vaginal delivery.
  5. ***Caput succedaneum*** is soft tissue swelling on any part of skull due to rupture of capillaries during delivery. Skull becomes normal within a few days in postnatal life (Fig. 1.21).

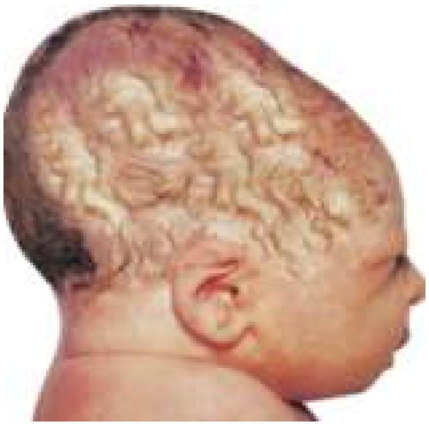


Fig. 1.21: Caput succedaneum

SEX DIFFERENCES IN THE SKULL

There are no sex differences until puberty. The postpubertal differences are listed in Table 1.5.

CRANIOMETRY

Craniometry is the process of recording various measurements of the skull.

Cephalic Index

It expresses the shape of the head, and is the proportion of breadth to length of the skull. Thus:

$$\text{Cephalic index} = \frac{\text{Maximum cranial breath}}{\text{Maximum cranial length}} \times 100$$

The length or the longest diameter is measured from the glabella to the occipital point, the breadth or the widest diameter is measured usually a little below the parietal tubera.

TABLE 1.5: Sex differences in the skull

Features	*Males*	*Females*
1. Weight	Heavier	Lighter
2. Size	Larger	Smaller
3. Capacity	Greater in males	10% less than males
4. Walls	Thicker	Thinner
5. Muscular ridges, glabella, superciliary arches, temporal lines, mastoid processes, superior nuchal lines and external occipital protuberance	More marked	Less marked
6. Tympanic plate	Larger and margins are more roughened	Smaller and margins are less roughened
7. Supraorbital margin	More rounded	Sharp
8. Forehead	Sloping (receding)	Vertical
9. Frontal and parietal tubera	Less prominent	More prominent
10. Vault	Rounded	Somewhat flattened

Note: Human races may be:

1. *Dolichocephalic* or long-headed when the index is 75 or less.
2. *Mesaticephalic* when the index is between 76 and 80.
3. *Brachycephalic* or short-headed or round-headed when the index is above 80.
4. Dolichocephaly is a feature of primitive races, like Eskimos, Negroes, etc.
5. Brachycephaly through mesaticephaly has been a continuous change in the advanced races, like the Europeans.

Facial Angle

This is the angle between two lines drawn from the nasion to the basion or anterior margin of foramen magnum and a line drawn from basion to the prosthion or central point on upper incisor alveolus (Fig. 1.9).

Facial angle is a rough index of the degree of development of the brain because it is the angle between facial skeleton, i.e. viscerocranium, and the calvaria, i.e. neurocranium, which are inversely proportional to each other. The angle is the smallest in the most evolved races of man, it is larger in lower races, and still larger in anthropoids.

Note:

Abnormal crania

1. ***Oxycephaly or acrocephaly, tower-skull, or steeple skull*** is an abnormally tall skull. It is due to premature closure of the suture between presphenoid and postsphenoid in the base, and the coronal suture in skull cap, so that the skull is very short anteroposteriorly. Compensation is done by the upward growth of skull for the enlarging brain.

2. ***Scaphocephaly or boat-shaped skull*** is due to premature synostosis in the sagittal suture; as a result, the skull is very narrow from side-to-side but greatly elongated.

Competency:
AN26.4 Describe morphological features of mandible.

MANDIBLE

The *mandible*, or the lower jaw, is the largest and the strongest bone of the face. It develops from the *1st pharyngeal arch*.

It is a horseshoe-shaped bone. It consists of three parts (Plate 1.14, Figs 1.22 and 1.23, Flowchart 1.14):

- *Body* – horizontally placed
- *Two rami* – vertically placed.

BODY OF MANDIBLE

Each half of the body has:
Two surfaces: External and internal
Two borders: Superior border or alveolar process and inferior border or base of the mandible.

Outer surface presents the following features:

1. ***Symphysis menti*** is the line at which the right and left halves of the bone meet each other. It is marked by a faint ridge.
2. ***Mental protuberance*** (*mentum* = chin) is a median triangular projecting area in the lower part of the midline. The inferolateral angles of the protuberance form the *mental tubercles*.
3. ***Mental foramen*** lies below the interval between the premolar teeth.
4. The *oblique line* is the continuation of the sharp anterior border of the ramus of the mandible. It runs downwards and forwards towards the mental tubercle.
5. The *incisive fossa* is a depression that lies just below the incisor teeth.

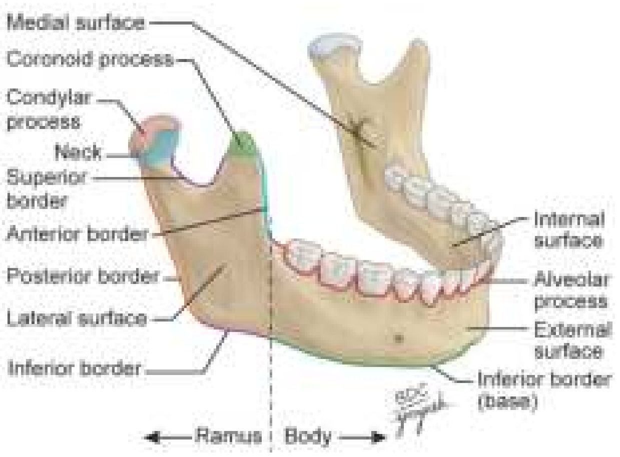

Medial surface
Coronoid process
Condylar process
Neck
Superior border
Anterior border
Posterior border
Lateral surface
Inferior border
Internal surface
Alveolar process
External surface
Inferior border (base)
Ramus
Body

Fig. 1.22: Parts of mandible

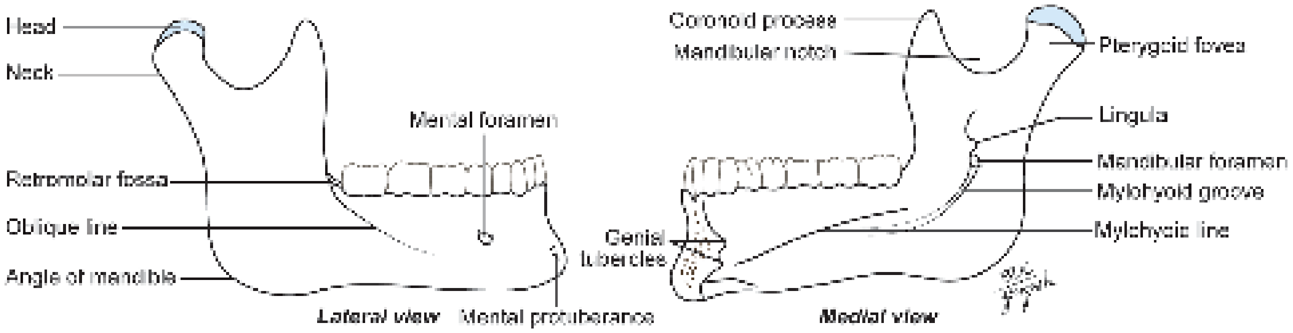

Head
Neck
Retromolar fossa
Oblique line
Angle of mandible
Mental foramen
Genial tubercles
Lateral view
Mental protuberance
Coronoid process
Mandibular notch
Pterygoid fovea
Lingula
Mandibular foramen
Mylohyoid groove
Mylohyoid line
Medial view

Fig. 1.23: Mandible (lateral and medial views)

Flowchart 1.14: Mandible

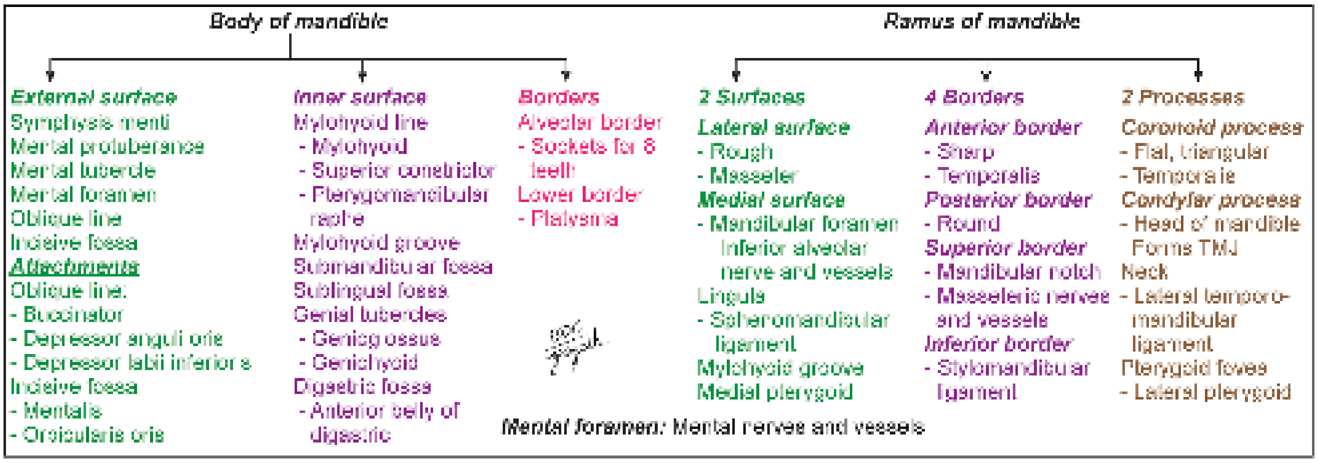
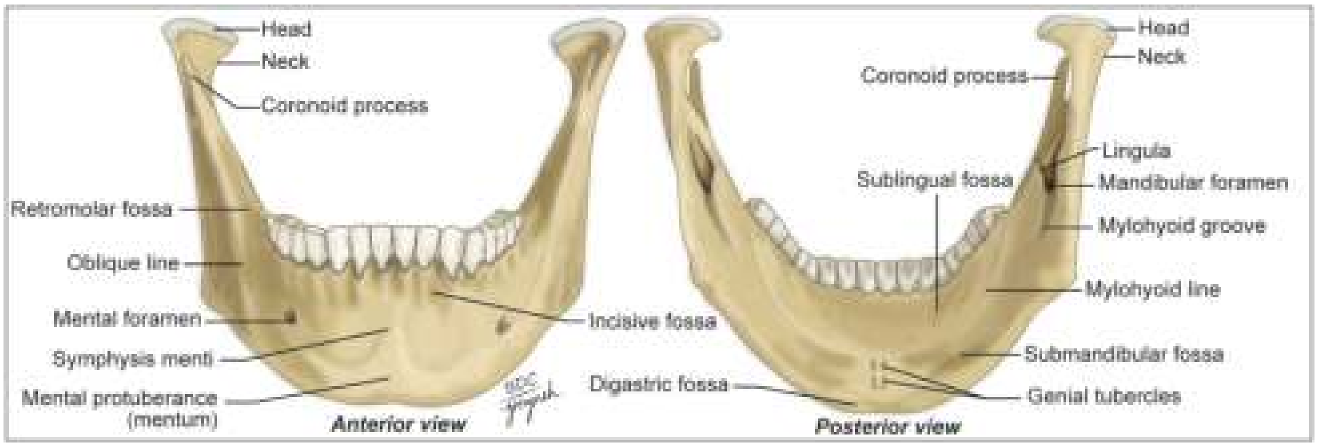

Body of mandible
External surface
Symphysis menti
Mental protuberance
Mental tubercle
Mental foramen
Oblique line
Incisive fossa
Attachments
Oblique line:
- Buccinator
- Depressor anguli oris
- Depressor labii inferioris
Incisive fossa
- Mentalis
- Orbicularis oris
Inner surface
Mylohyoid line
- Mylohyoid
- Superior constrictor
- Pterygomandibular raphe
Mylohyoid groove
Submandibular fossa
Sublingual fossa
Genial tubercles
- Genioglossus
- Geniohyoid
Digastric fossa
- Anterior belly of digastric
Borders
Alveolar border
- Sockets for 8 teeth
Lower border
- Platysma
Mental foramen: Mental nerves and vessels
Ramus of mandible
2 Surfaces
Lateral surface
- Rough
- Masseter
Medial surface
- Mandibular foramen
Inferior alveolar nerve and vessels
Lingula
- Sphenomandibular ligament
Mylohyoid groove
Medial pterygoid
4 Borders
Anterior border
- Sharp
- Temporalis
Posterior border
- Round
Superior border
- Mandibular notch
- Masseteric nerves and vessels
Inferior border
- Stylomandibular ligament
2 Processes
Coronoid process
- Flat, triangular
- Temporalis
Condylar process
- Head of mandible
Forms TMJ
Neck
- Lateral temporomandibular ligament
Pterygoid fovea
- Lateral pterygoid

Plate 1.14: Mandible



Inner surface presents the following features:

1. ***Mylohyoid line*** is a prominent ridge that runs obliquely downwards and forwards from below the third molar tooth to the median area below the genial tubercles (*see* below). The mylohyoid groove (present on the ramus) extends onto the body below the posterior end of the mylohyoid line.
2. Below the mylohyoid line, the surface is slightly hollowed out to form the ***submandibular fossa***, which lodges the submandibular gland.
3. Above the mylohyoid line, there is the *sublingual fossa* in which the sublingual gland lies.
4. The posterior surface of the symphysis menti is marked by four small elevations called the *superior and inferior* ***genial tubercles***.

Upper or alveolar border bears sockets for the teeth.

Lower border of the mandible is also called the *base*. Near the midline, the base shows an oval depression called the *digastric fossa*.

RAMUS

The ramus is quadrilateral in shape and has:

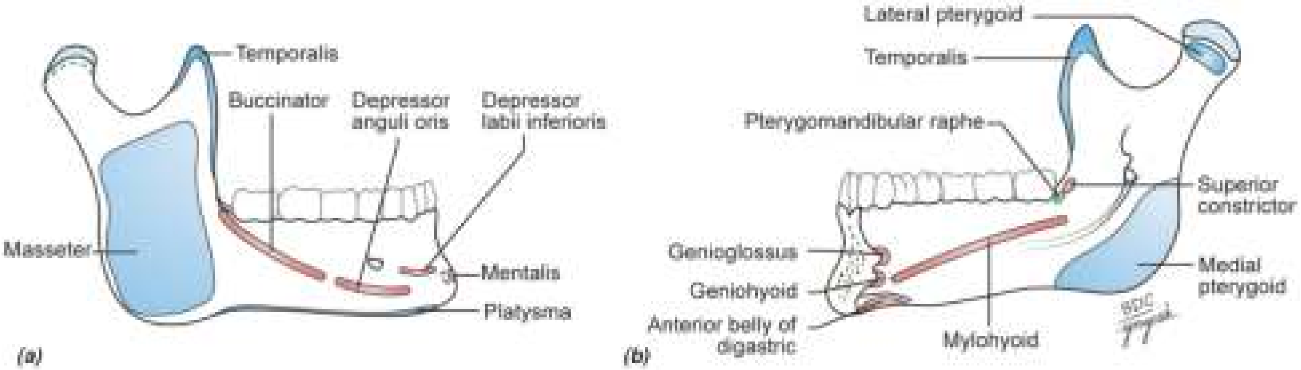
- *Two surfaces* — lateral and medial
- *Four borders* — upper, lower, anterior and posterior
- *Two processes* — coronoid and condyloid.

- ***Lateral surface*** is flat and bears a number of oblique ridges.
- ***Medial surface*** presents the following features:
  1. ***Mandibular foramen*** lies a little above the centre of ramus at the level of occlusal surfaces of the teeth. It leads into the *mandibular canal*, which descends into the body of the mandible and opens at the *mental foramen* (Fig. 1.23).
  2. The anterior margin of the mandibular foramen is marked by a sharp tongue-shaped projection called the ***lingula***. The lingula is directed towards the head or condyloid process of the mandible.
  3. The *mylohyoid groove* begins just below the mandibular foramen, and runs downwards and forwards to be gradually lost over the submandibular fossa.
- ***Upper border*** of the ramus is thin and is curved downwards forming the *mandibular notch.*
- ***Lower border*** is the backward continuation of the base of the mandible. Posteriorly, it ends by becoming continuous with the posterior border at the *angle* of the mandible (Fig. 1.23).
- ***Anterior border*** is thin, while the *posterior border* is thick.
- ***Coronoid process*** (Greek *crow's beak*) is a flattened triangular upward projection from the anterosuperior part of the ramus. Its anterior border is continuous with the anterior border of the ramus. The posterior border bounds the mandibular notch.
- ***Condyloid process*** (Latin *knuckle-like*) is a strong upward projection from the posterosuperior part of the ramus. Its upper end is expanded from side-to-side to form the ***head***. The head is covered with fibrocartilage and articulates with the temporal bone to form the temporomandibular joint. The constriction below the head is the ***neck***. Its anterior surface presents a depression called the ***pterygoid fovea***.

ATTACHMENTS AND RELATIONS OF THE MANDIBLE

Muscles

1. The oblique line on the lateral side of the body gives origin to the buccinator as far forwards as the anterior border of the first molar tooth. In front of this origin, the depressor labii inferioris and the depressor anguli oris arise from the oblique line below the mental foramen (Figs 1.24a and b).
2. The incisive fossa gives origin to the mentalis and mental slips of the orbicularis oris.
3. The parts of both the inner and outer surfaces just below the alveolar margin are covered by the mucous membrane of the mouth.
4. Mylohyoid line gives origin to the mylohyoid muscle.
5. Superior constrictor muscle of the pharynx arises from an area above the posterior end of the mylohyoid line.
6. *Upper genial tubercle* gives origin to the genioglossus, and the *lower tubercle* to geniohyoid.



Figs 1.24a and b: Attachments of the mandible: (a) Lateral surface of the right half of the mandible and (b) inner surface of right half of the mandible

7. Anterior belly of the digastric muscle arises from the digastric fossa.
8. Platysma is inserted into the lower border.
9. Whole of the lateral surface of ramus except the posterosuperior part provides insertion to the masseter muscle.
10. Medial pterygoid muscle is inserted on the medial surface of the ramus, on the roughened area below and behind the mylohyoid groove.
11. Temporalis is inserted into the apex and medial surface of the coronoid process. The insertion extends downwards on the anterior border of the ramus.
12. Lateral pterygoid muscle is inserted into the pterygoid fovea on the anterior aspect of the neck.

Ligaments

1. Pterygomandibular raphe is attached immediately behind the third molar tooth in continuation with the origin of superior constrictor.
2. Deep cervical fascia (investing layer) is attached to the whole length of lower border.
3. Sphenomandibular ligament is attached to the lingula.
4. The lateral surface of neck provides attachment to the lateral ligament of the temporomandibular joint.
5. Stylomandibular ligament is attached to the angle of the mandible.

NERVES AND VESSELS RELATED TO THE MANDIBLE (Figs 1.25a and b)

1. The mental foramen transmits the *mental nerve and vessels*.
2. The *inferior alveolar nerve and vessels* enter the *mandibular canal through the mandibular foramen*, and run forwards within the canal.
3. The *mylohyoid nerve and vessels* lie in the *mylohyoid groove*.
4. The *lingual nerve* is related to the medial surface of the ramus in front of the mylohyoid groove.
5. The area above and behind the mandibular foramen is related to the *inferior alveolar nerve and vessels* and to the *maxillary artery*.
6. The *masseteric nerve and vessels* pass through the mandibular notch.
7. The *auriculotemporal nerve* and *superficial temporal artery* are related to the medial side of the neck of mandible.
8. Facial artery is palpable on the lower border of mandible at anteroinferior angle of masseter.

Note: Facial and maxillary arteries are not accompanied by respective nerves. The lingual nerve does not get company of its artery.

Structures related to mandible

1. Salivary glands: Parotid, submandibular and sublingual.
2. Lymph nodes: Parotid, submandibular and submental.
3. Arteries (7): Maxillary, superficial temporal, masseteric, inferior alveolar, mylohyoid, mental and facial.
4. Nerves (6): Lingual, auriculotemporal, masseteric, inferior alveolar, mylohyoid and mental.
5. Muscles of mastication: Insertions of temporalis, masseter, medial pterygoid and lateral pterygoid.
6. Ligaments: Lateral ligament of temporomandibular joint, stylomandibular ligament, sphenomandibular and pterygomandibular raphe.

[*Mnemonics*

Nerves related to mandible M^3***LIA:*** **M^3–** masseteric nerve, mental nerve and nerve to mylohyoid; **L–** lingual nerve; I– inferior alveolar nerve, **A**– auriculotemporal nerve.

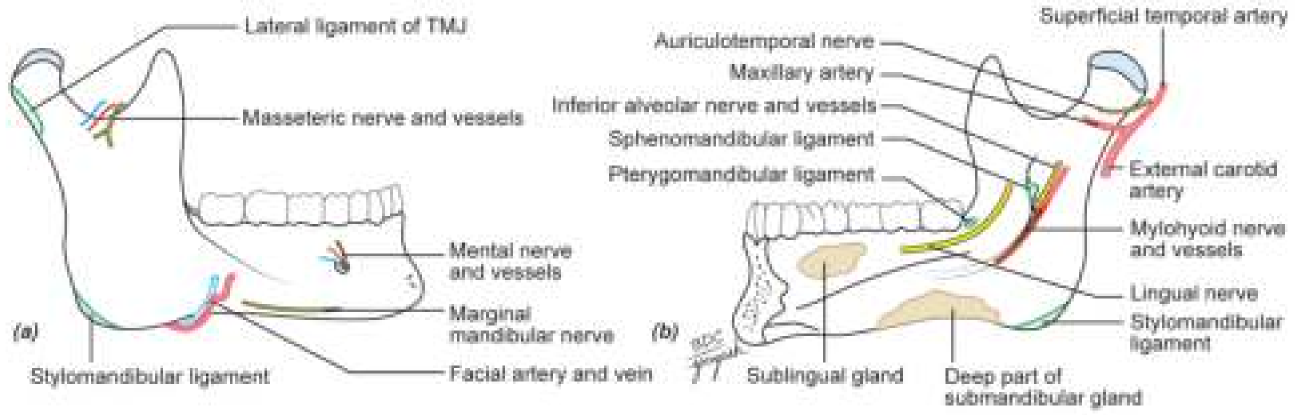
Arteries related to mandible: M^4***IFS:*** **M^4**– masseteric, maxillary, mental arteries and artery to mylohyoid; **I**– inferior alveolar artery, **F**– facial artery, **S**– superficial temporal artery; forearm and hand].

OSSIFICATION

The mandible is the *second bone, next to the clavicle, to ossify* in the body. Its greater part ossifies *in membrane*. The parts ossifying in *cartilage* include the *incisive part* below the incisor teeth, the *coronoid and condyloid processes* and the *upper half of the ramus* above the level of the mandibular foramen.

Each half of the mandible ossifies from only one *centre*, which appears at about the 6*th week* of intrauterine life in the mesenchymal *sheath of Meckel's cartilage* near the future mental foramen. Meckel's cartilage is the skeletal element of 1*st pharyngeal arch*.

At birth, the mandible consists of two halves connected at the *symphysis menti* by fibrous tissue. Bony union takes place during the first year of life.


Lateral ligament of TMJ
Masseteric nerve and vessels
Mental nerve and vessels
Marginal mandibular nerve
Facial artery and vein
Stylomandibular ligament
(a)
Superficial temporal artery
Auriculotemporal nerve
Maxillary artery
Inferior alveolar nerve and vessels
Sphenomandibular ligament
Pterygomandibular ligament
External carotid artery
Mylohyoid nerve and vessels
Lingual nerve
Stylomandibular ligament
(b)
Sublingual gland
Deep part of submandibular gland

Figs 1.25a and b: Relations of the mandible: (a) Lateral surface of the right half of the mandible and (b) inner surface of right half of the mandible

AGE CHANGES IN THE MANDIBLE

The mandible shows considerable changes with age. The changes are observed in the following points (Fig. 1.26, Table 1.6):

1. Position of mental foramen
2. Angle of mandible
3. Relationship between condylar and coronoid processes
4. Location of mandibular canal
5. Alveolar process and teeth.

CLINICAL ANATOMY

- The mandible is commonly fractured at the canine socket where it is weak.
- Involvement of the inferior alveolar nerve in the callus may cause neuralgic pain, which may be referred to the areas of distribution of the buccal and auriculotemporal nerves. If the nerve is damaged, the areas supplied by these nerves become insensitive.
- The next common fracture of the mandible occurs at the angle and neck of mandible. Toothache of lower jaw referred to external auditory meatus, as both are supplied by branches of mandibular division of trigeminal nerve.

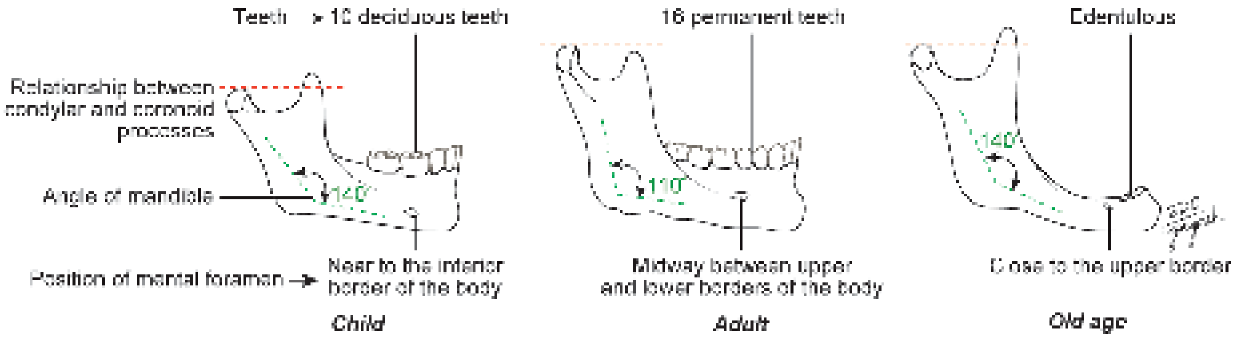

Teeth
10 deciduous teeth
16 permanent teeth
Edentulous
Relationship between condylar and coronoid processes
Angle of mandible
140°
110°
140°
Position of mental foramen
Near to the inferior border of the body
Midway between upper and lower borders of the body
Close to the upper border
Child
Adult
Old age

Fig 1.26: Age changes in the mandible

TABLE 1.6: Age changes in mandible

Feature	*In children*	*In adult*	*In old age*
Angle of mandible	140°	110°	140°
Direction of mental foramen	Upward and backward	Horizontally backward	Forward
Position of mental foramen	Near the inferior border of the body	Midway between upper and lower borders of the body	Close to the upper border
Alveolar process	Rudimentary	Well-developed	Absorbed to form alveolar ridge, edentulous
Teeth	Ten deciduous teeth	16 permanent teeth	Edentulous
Relationship between condylar and coronoid processes	Coronoid process lies at a higher level than condylar process	Condylar process lies at a higher level than the coronoid process	Coronoid process lies at higher level than the condylar process
Height of body	Gradually increases	Maximum	Gradually decreases
Position of mandibular body	Runs near the lower border	Runs parallel to the mylohyoid line	Runs close to the upper border

MAXILLA

Maxilla (cheek) is the second largest bone of the face, the first being the mandible. The two maxillae form the whole of the upper jaw (Plate 1.15).

SIDE DETERMINATION

1. Anterior surface ends medially into a deeply concave border, called the *nasal notch*. Posterior surface is convex.
2. Alveolar border with sockets for upper teeth faces downwards with its convexity directed outwards. Frontal process is the longest process, which is directed upwards.
3. Medial surface is marked by a large irregular penning, the *maxillary hiatus*/antrum of Highmore for maxillary air sinus.

FEATURES

Each maxilla consists of (Plate 1.15):

1. Body
2. Four processes: Frontal, zygomatic, palatine and alveolar.

Body of Maxilla

It is pyramidal in shape, with its base directed medially at the nasal surface, and the apex directed laterally at the zygomatic process. It has four surfaces and encloses a large cavity, the *maxillary sinus* described in Chapter 15, page 252.

It has four surfaces:

1. Anterior or facial,
2. Posterior or infratemporal,
3. Superior or orbital and
4. Medial or nasal.

Anterior or Facial Surface

1. Anterior surface forms a part of norma frontalis.
2. Above the incisor teeth, there is a slight depression, the *incisive fossa,* which gives origin to depressor septi. Incisivus labii superioris (part of orbicularis oris) arises from the alveolar margin below the fossa, and the *nasalis* superolateral to the fossa along the nasal notch.
3. Lateral to canine eminence, there is a larger and deeper depression, the *canine fossa,* which gives origin to levator anguli oris.
4. Above the canine fossa, there is *infraorbital foramen*, which transmits *infraorbital nerve and vessels*.
5. Levator labii superioris arises between the infraorbital margin and infraorbital foramen.
6. Medially, the anterior surface ends in a deeply concave border, the nasal notch, which terminates below into a process that, along with the corresponding process of the opposite maxilla, forms the anterior nasal spine. Anterior surface bordering the nasal notch gives origin to nasalis and depressor septi.

Posterior or Infratemporal Surface

1. It forms the anterior wall of *infratemporal fossa*, and is separated from anterior surface by the zygomatic process and a rounded ridge, which descends from the process of the first molar tooth.
2. Near the centre of the surface open two or three *alveolar canals* for *posterior superior alveolar nerve and vessels.*
3. Posteroinferiorly, there is a rounded eminence, the ***maxillary tuberosity***, which articulates superomedially with pyramidal process of palatine bone, and gives origin laterally to the superficial head of medial pterygoid muscle.
4. Above the maxillary tuberosity, the smooth surface forms anterior wall of *pterygopalatine fossa*, and is grooved by *maxillary nerve.*

Superior or Orbital Surface

1. Superior surface is smooth, triangular and slightly concave, and forms the greater part of the *floor of orbit*.
2. The surface presents *infraorbital groove* leading forwards to *infraorbital canal*, which opens on the anterior surface as *infraorbital foramen*. The groove, canal and foramen transmit the *infraorbital nerve and vessels*. Near the midpoint, the canal gives off laterally a branch, the *canalis sinuous*, for the passage of *anterior superior alveolar nerve and vessels*.
3. Inferior oblique muscle of eyeball arises from a depression just lateral to lacrimal notch at the anteromedial angle of the surface.

Medial or Nasal Surface

1. Medial surface forms a part of the *lateral wall of nose*.
2. *Posterosuperiorly*, it displays a large irregular opening of the maxillary sinus, the *maxillary hiatus*.
3. Below the hiatus, the smooth concave surface forms a part of *inferior meatus of nose*.
4. Behind the hiatus, the surface articulates with perpendicular plate of palatine bone, enclosing the *greater palatine canal*, which runs downwards and forwards, and transmits *greater palatine vessels and the anterior, middle and posterior palatine nerves*.
5. In front of the hiatus, there is *nasolacrimal groove*, which is converted into the nasolacrimal canal by articulation with the *descending process of lacrimal bone* and the *lacrimal process of inferior nasal concha*. The canal transmits *nasolacrimal duct to the inferior meatus of nose*.
6. More anteriorly, an oblique ridge forms the *conchal crest* for articulation with the inferior nasal concha.
7. Above the conchal crest, the shallow depression forms a part of the *atrium of middle meatus* of nose.

Processes of Maxilla

It has four processes: Frontal, zygomatic, palatine and alveolar (Plate 1.15).

Zygomatic Process

The zygomatic process is a pyramidal lateral projection that articulates with the zygomatic bone.

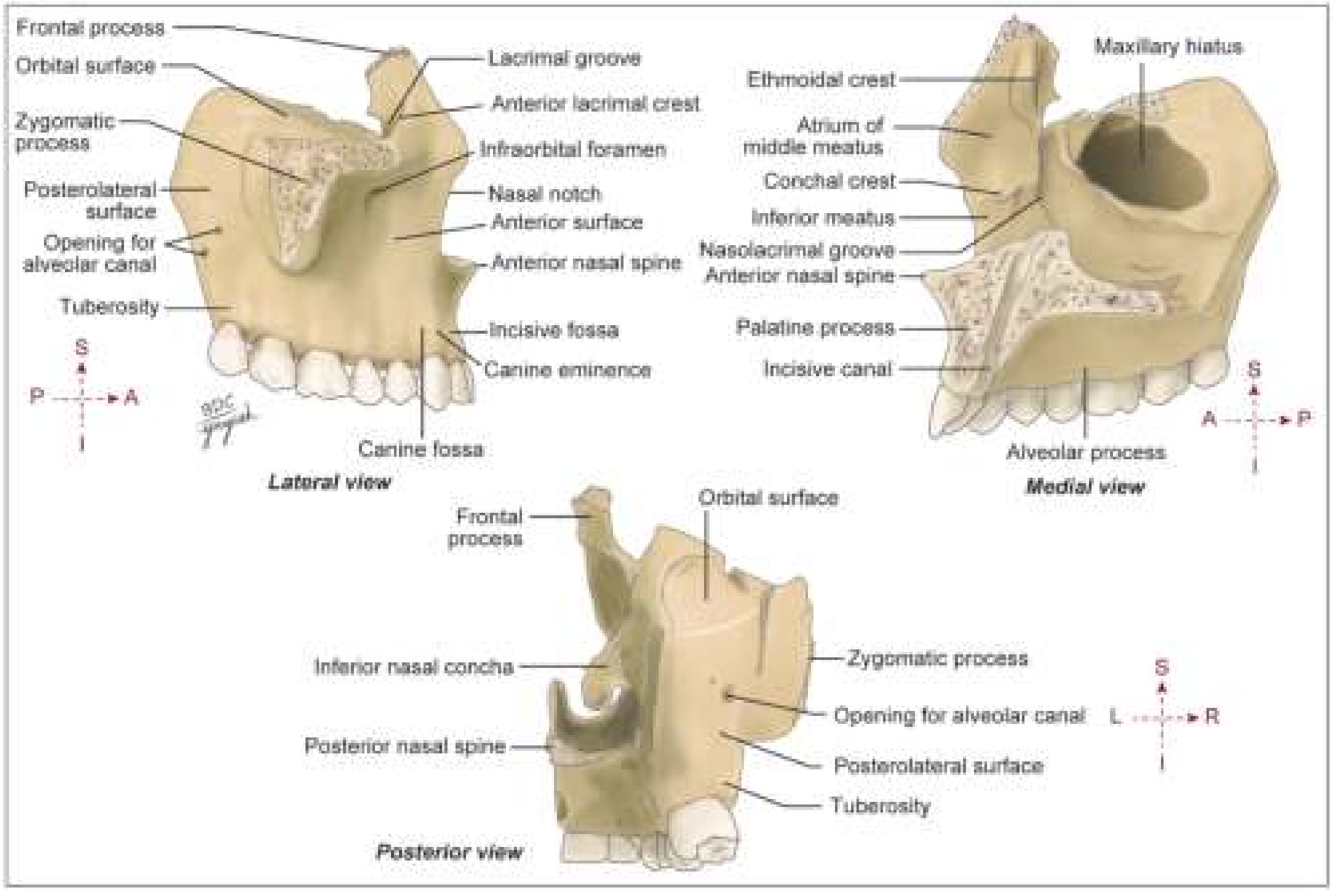

Frontal process
Orbital surface
Zygomatic process
Posterolateral surface
Opening for alveolar canal
Tuberosity
S
P
A
I
Lacrimal groove
Anterior lacrimal crest
Infraorbital foramen
Nasal notch
Anterior surface
Anterior nasal spine
Incisive fossa
Canine eminence
Canine fossa
Lateral view
Ethmoidal crest
Atrium of middle meatus
Conchal crest
Inferior meatus
Nasolacrimal groove
Anterior nasal spine
Palatine process
Incisive canal
Maxillary hiatus
Alveolar process
Medial view
S
A
P
I
Frontal process
Orbital surface
Inferior nasal concha
Posterior nasal spine
Zygomatic process
Opening for alveolar canal
Posterolateral surface
Tuberosity
Posterior view
S
L
R
I

Plate 1.15: Right maxilla

Frontal Process

1. The frontal process projects upwards to *articulate* above with the frontal bone, in front with nasal bone and behind with lacrimal bone.
2. *Lateral surface* is divided by a vertical ridge, the ***anterior lacrimal crest***, into a smooth anterior part and a grooved posterior part.
3. The anterior lacrimal crest gives attachment to lacrimal fascia and the medial palpebral ligament. The anterior smooth area gives origin to the orbital part of orbicularis oculi and levator labii superioris alaeque nasi. The posterior grooved area forms the anterior half of the floor of *lacrimal groove*.
4. *Medial surface* of the frontal process has horizontal *ethmoidal crest* that articulates with middle nasal concha. The area below the ethmoidal crest is hollowed out to form the atrium of the middle meatus of nose.

Alveolar Process

1. The alveolar process forms half of the alveolar arch, and bears sockets for the roots of upper 8 teeth.
2. Buccinator arises from the posterior part of its outer surface up to the 1st molar tooth.

Palatine Process

1. Palatine process is a thick horizontal plate projecting medially to form a part of the hard.
2. Its medial border is raised superiorly to form the *nasal crest*. The groove between the nasal crests of two maxillae receives lower border of vomer; anterior part of the ridge is high and is known as *incisor crest*, which terminates anteriorly into the anterior nasal spine.
3. Incisive canal traverses near the anterior part of the medial border.

Note: The maxilla and premaxilla ossify from primary ossification centres that appear in 7th week of intrauterine life and three secondary ossification centres that appear in 8th week after birth. The premaxilla fuse with alveolar process almost immediately after the ossification. There is no evidence of a separate centre of ossification for the incisor-bearing portion of the maxilla (premaxilla). A small maxillary sinus is present at birth which enlarges until the eruption of permanent dentition.

PARIETAL BONE

Two parietal bones form a large part of the roof and sides of vault of skull. Each bone is roughly quadrilateral in shape with its convexity directed outwards (Plate 1.16).

SIDE DETERMINATION

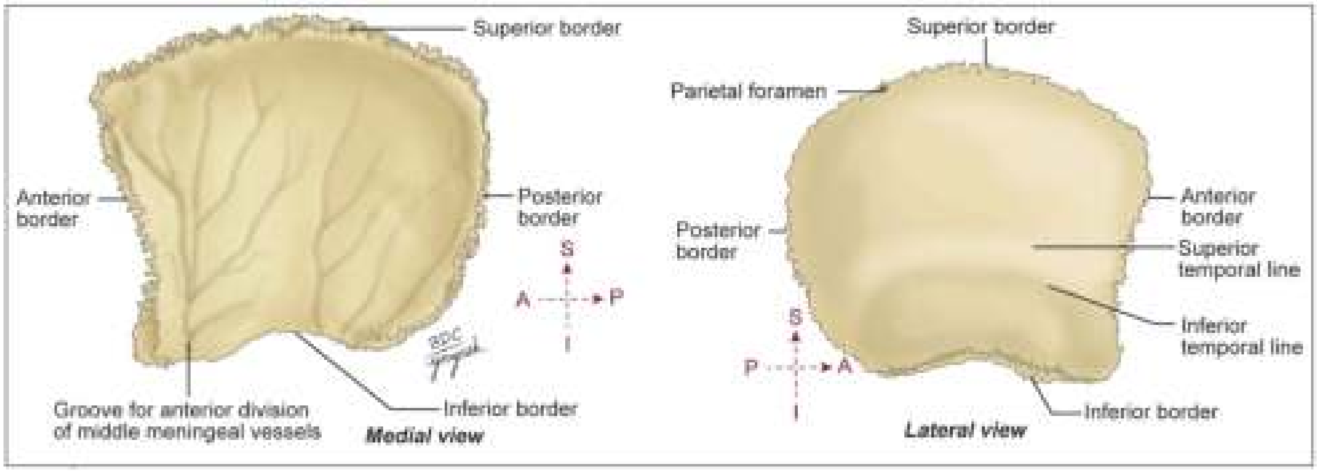
Outer surface is convex and smooth, inner surface is concave and depicts vascular markings.

Anteroinferior angle is pointed and shows a groove for anterior division of middle meningeal artery.

FEATURES

Parietal bone has two surfaces, four borders and four angles (Plate 1.16).

Plate 1.16: Parietal bone (medial and lateral views)


Superior border
Anterior border
Posterior border
S
A
P
I
Groove for anterior division of middle meningeal vessels
Inferior border
Medial view
Superior border
Parietal foramen
Posterior border
Anterior border
Superior temporal line
Inferior temporal line
S
P
A
I
Inferior border
Lateral view

Surfaces

1. Outer convex
2. Inner concave

Borders

1. Superior or sagittal
2. Inferior or squamosal
3. Anterior or frontal
4. Posterior or occipital

Angles

1. Anterosuperior or frontal
2. Anteroinferior or sphenoidal
3. Posterosuperior or occipital
4. Posteroinferior or mastoid

   At each of the four angles, are four fontanelles. These are:
   a. One anterior fontanelle
   b. One posterior fontanelle
   c. Two anterolateral or sphenoidal fontanelles
   d. Two posterolateral or mastoid fontanelles.

Details can be studied from *norma verticalis* and *norma lateralis* and *inner aspect of skull cap*.

OCCIPITAL BONE

Single occipital bone occupies posterior and inferior parts of the skull (Plate 1.17).

ANATOMICAL POSITION

It is concave forwards and encloses the largest foramen of skull, foramen magnum, through which cranial cavity communicates with the vertebral canal. On each side of foramen magnum is the occipital condyle, which articulates with atlas vertebra.

FEATURES

Occipital bone is divided into three parts (Plate 1.17):

1. Squamous part – expanded plate of the bone that lies behind the foramen magnum.
2. Basilar part – lies in front of foramen magnum.
3. Condylar or lateral part – on each side of foramen magnum.

Squamous Part

Comprises two surfaces, three angles and four borders.

Surfaces: External convex surface and internal concave surface.

Angles: One superior angle and two lateral angles.

Borders: Two lambdoid borders in upper part and two mastoid borders in lower part.

Basilar Part

The basilar part of occipital bone is called basiocciput. It articulates with basisphenoid to form the base of skull. It is quadrilateral in shape and comprises two surfaces and four borders.

Surfaces are superior and inferior.

Borders are anterior, posterior and two lateral, on each side.

Condylar Part

It comprises:

- Superior surface
- Inferior surface which shows occipital condyles and hypoglossal canal.

The details can be read from descriptions of *norma occipitalis* and *posterior cranial fossa*.

FRONTAL BONE

Frontal bone forms the forehead, most of the roof of orbit, and most of the floor of anterior cranial fossa. Its parts are squamous, orbital and nasal parts (Plate 1.18).

ANATOMICAL POSITION

Squamous part is vertical and is convex forwards. Two orbital plates are horizontal thin plates projecting backwards. Nasal part is directed forwards and downwards.

Plate 1.17: Occipital bone (#: posterior condylar canal)

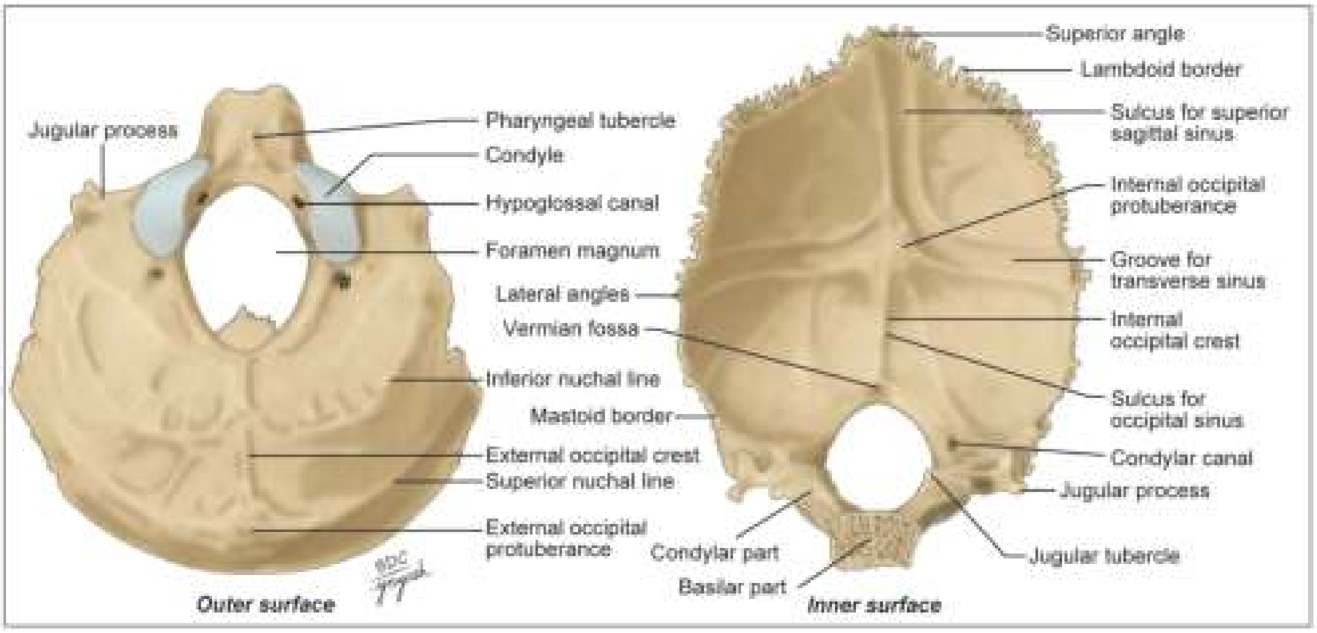
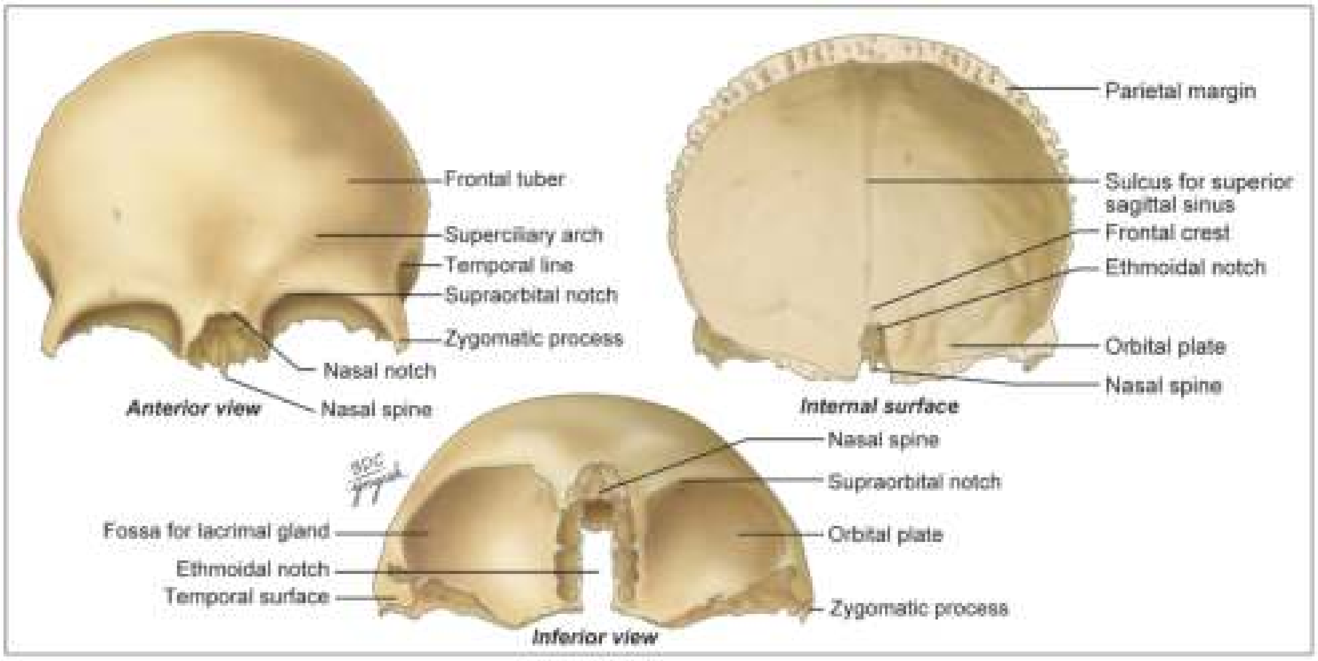

Jugular process
Pharyngeal tubercle
Condyle
Hypoglossal canal
Foramen magnum
Lateral angles
Vermian fossa
Inferior nuchal line
Mastoid border
External occipital crest
Superior nuchal line
External occipital protuberance
Outer surface
Superior angle
Lambdoid border
Sulcus for superior sagittal sinus
Internal occipital protuberance
Groove for transverse sinus
Internal occipital crest
Sulcus for occipital sinus
Condylar canal
Jugular process
Jugular tubercle
Condylar part
Basilar part
Inner surface

Plate 1.18: Frontal bone


Frontal tuber
Superciliary arch
Temporal line
Supraorbital notch
Zygomatic process
Nasal notch
Nasal spine
Anterior view
Parietal margin
Sulcus for superior sagittal sinus
Frontal crest
Ethmoidal notch
Orbital plate
Nasal spine
Internal surface
Nasal spine
Supraorbital notch
Orbital plate
Zygomatic process
Fossa for lacrimal gland
Ethmoidal notch
Temporal surface
Inferior view

Squamous Part

The squamous part presents two surfaces, two borders and encloses a pair of frontal air sinuses.

Outer Surface

It is smooth and shows:

1. Frontal tuberosity
2. Superciliary arches
3. Glabella
4. Frontal air sinus is a cavity within outer and inner tables of frontal bone, divided by a bony septum into two parts
5. Metopic suture
6. Upper or parietal border: Articulates with parietal bone
7. Lower or orbital border: Free, presents supra-orbital notch foramen
8. Zygomatic process
9. Temporal line and temporal surfaces.

Inner Surface

It is concave and presents:

1. Sagittal sulcus
2. Frontal crest

Orbital Parts (Plates)

Orbital plates are separated from each other by a wide gap – the ethmoidal notch.

Orbital or inferior surface of the plate is smooth and presents lacrimal fossa anterolaterally and trochlear spine anteromedially.

Ethmoidal notch is occupied by cribriform plate of ethmoid bone. On each side of notch are small air spaces, which articulate with the labyrinth of ethmoid to complete ethmoidal air sinuses. At the margins are anterior and posterior ethmoidal canals.

Nasal Part

Lies between two supraorbital margins. The margins of the nasal notch on each side articulate with nasal, frontal process of maxilla and lacrimal bones.

Details can be studied from descriptions of *norma frontalis, norma lateralis, inner aspect of skull cap and anterior cranial fossa*.

TEMPORAL BONE

Temporal bones are situated at the sides and base of skull (Plate 1.19).

SIDE DETERMINATION

- Plate-like squamous part is directed upwards and laterally.
- Strong zygomatic process is directed forwards.
- Petromastoid part, triangular in shape, is directed medially.
- External acoustic meatus, enclosed between squamous and tympanic parts, is directed laterally.

FEATURES

The temporal bone consists of the following parts (Plate 1.19):

1. Squamous
2. Mastoid
3. Petrous
4. Tympanic
5. Styloid process.

Squamous Part

It is expanded, thin, translucent portion of the bone. It shows the following features:

1. *Temporal or external surface:* It forms the greater part of the temporal fossa. It gives origin to the temporalis muscle.
2. *Groove for middle temporal vessels* is a vertical groove that ascends upward from the external acoustic meatus.
3. *Supramastoid crest* is a curved ridge that ascends upward and backward from the anterior part of the external acoustic meatus. It gives attachment to the *temporal fascia* and marks the posterior boundary of the temporal fossa.
4. *Auricularis posterior* muscle arises from the space between the supramastoid crest and the line of the squamomastoid suture.
5. *Suprameatal spine* is a bony projection on the medial side of the suprameatal triangle.
6. *Internal surface* is concave. It is marked by irregular impressions for the temporal gyri and presents grooves for the middle meningeal vessels.

Zygomatic Process of the Temporal Bone

It forms an elongated bony process. It articulates with the temporal process of the zygomatic bone to form the *zygomatic arch*. It consists of

Two roots: *anterior and posterior*
Elongated thin anterior part.

1. *Roots of the zygomatic process* are anterior and posterior, and they converge to meet at a point to form a tubercle known as the *tubercle of the root of the zygoma*. It gives attachment to the *lateral temporomandibular ligament*.
2. At the tubercle, the process is twisted and the thin anterior part projects forward from it.
3. The *anterior root of the zygoma* projects horizontally lateralward and its inferior surface is convex and smooth. It forms a thickened bar of the bone in front of the articular fossa and is known as the *articular tubercle* (*eminence*).
4. The *posterior root* is directed downward and forward. It is continuous behind with the supramastoid crest and in front with the superior border of the thin anterior part of the zygoma.
5. The thin anterior part of the zygomatic process is subcutaneous.
6. The medial surface and inferior border of zygomatic process give origin to *masseter* muscle. Its superior border gives attachment to the *temporal fascia*.

Mandibular Fossa

It is formed partly by the squamous part and partly by the tympanic part. It consists of:

a. an *articular part* formed by the squamous part of the temporal bone, and
b. a *nonarticular part* formed by the tympanic part of the bone.

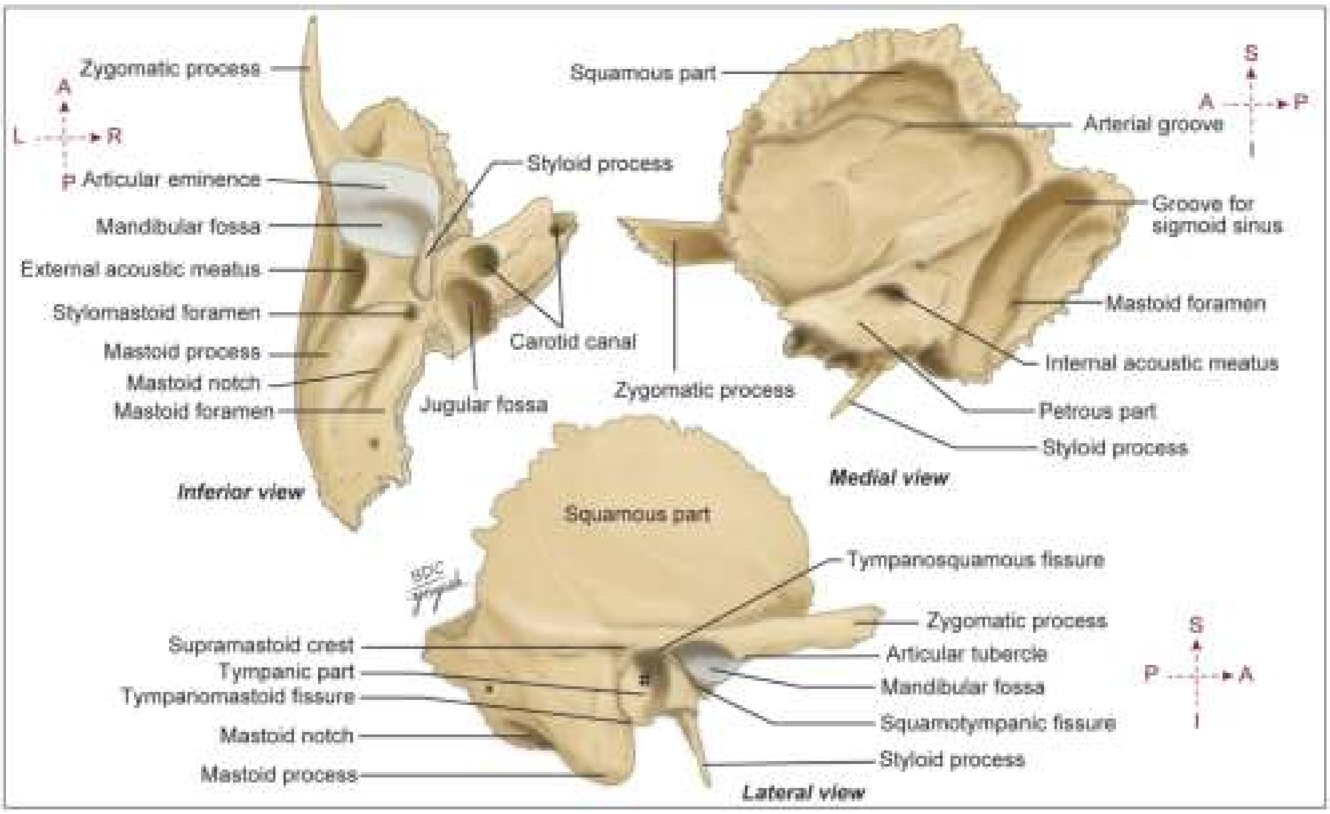
1. *Squamotympanic fissure* separates the articular part from the tympanic part medially.
2. The downturned anterolateral portion of the *tegmen tympani* projects into this fissure and subdivides it into *petrotympanic and petrosquamosal fissures*.
3. *Petrotympanic fissure* communicates with the tympanic cavity. It transmits *anterior ligament of the malleus* and *anterior tympanic branch* of the maxillary artery. It has *anterior canaliculus* for the chorda tympani nerve at its medial end. This canal transmits the *chorda tympani nerve*.

Mastoid Part

It is thick. It presents the following features:

1. *External surface* is convex.

Plate 1.19: Right temporal bone


Zygomatic process
A
L
R
P
Articular eminence
Mandibular fossa
External acoustic meatus
Stylomastoid foramen
Mastoid process
Mastoid notch
Mastoid foramen
Styloid process
Carotid canal
Jugular fossa
Inferior view
Squamous part
Arterial groove
S
A
P
I
Groove for sigmoid sinus
Mastoid foramen
Internal acoustic meatus
Petrous part
Styloid process
Zygomatic process
Medial view
Squamous part
Tympanosquamous fissure
Zygomatic process
Articular tubercle
Mandibular fossa
Squamotympanic fissure
Styloid process
Supramastoid crest
Tympanic part
Tympanomastoid fissure
Mastoid notch
Mastoid process
Lateral view
S
P
A
I

2. It forms a conical projection known as the ***mastoid process***. It gives
   i. Origin to *occipital belly of the occipitofrontalis*
   ii. Insertion to the sternocleidomastoid, splenius capitis and longissimus capitis (from above downward).
3. ***Mastoid notch*** on the medial aspect of the mastoid process gives origin to the *posterior belly of the digastric* muscle.
4. *Groove* located below the digastric lodges the *occipital artery*.
5. *Mastoid foramen* lies below the groove for the occipital artery and close to the posterior border of the mastoid process.
6. The internal surface of the mastoid part is marked by a deep curved groove for sigmoid sinus. The mastoid foramen opens into its floor.
7. **Section of the mastoid part**
   1. It contains a number of irregular *mastoid air cells*.
   2. *Mastoid or tympanic antrum*: It is a large irregular space situated at the upper and anterior portions of the mastoid part.

Petrous Part

It forms a cylindrical process of bone. It lies between the greater wing of the sphenoid and the occipital bone at the base of the skull.

1. *Base* of the petrous part is fused with the squamous and the mastoid parts, and the apex articulates with the petrosal process of the sphenoid. It is directed upward, forward and medially.
2. *Anterior surface* of the petrous part lies in the middle cranial fossa and is marked by impressions for the temporal lobe of the brain. Immediately behind the apex, this surface presents a depression known as the *trigeminal impression*. It lodges the *trigeminal ganglion*. Behind the trigeminal impression, there is an eminence known as the *arcuate eminence*. It is formed by the *superior semicircular canal* of the internal ear.
3. *Tegmen tympani*
   - On the lateral side of the anterior surface, there is a thin plate of bone called the *tegmen tympani*. It forms the roof of the tympanic antrum, tympanic cavity and the canals for the tensor tympani and the auditory tube.
   - Laterally, the tegmen tympani is bend itself and descends downward on the medial side of the squamous part and forms the lateral wall of the auditory tube.
   - Its anterolateral portion projects into the squamotympanic fissure.
   - On the anterior part of the tegmen tympani, there is a faint groove that leads posteriorly into an *opening for the greater superficial petrosal nerve*.
   - Lateral to this opening, there is another *opening for the lesser petrosal nerve*.
   - *Posterior surface* forms the anterior part of the posterior cranial fossa.
4. *Internal acoustic meatus* is a circular aperture. It extends laterally for about 1 cm.

5. Bottom of the internal auditory meatus is closed by *perforated plate* of bone for the transmission of nerve rootlets of vestibulocochlear nerve.
6. *Inferior surface* of the petrous part is faced downward. Close to the apex, it gives origin to the levator veli palatini muscle.
   - It shows a circular opening of the *carotid canal*, which transmits the *internal carotid artery* with its plexus of sympathetic nerves.
   - Behind the carotid opening there is *jugular fossa*, which lodges the *superior bulb of the internal jugular vein*.
   - At the jugular fossa, there is *tympanic canaliculus* that transmits the *tympanic branch of the glossopharyngeal nerve*.
   - *Jugular surface*: It is a small quadrilateral articular area behind the jugular fossa. It articulates with the jugular process of the occipital bone.
   - *Mastoid canaliculus*: It a small foramen on the lateral wall of the jugular fossa. It transmits the *auricular branch of the vagus nerve*.
   - *Styloid process*: It is a slender process that projects downward.
   - *Stylomastoid foramen*: It lies behind the styloid process. It gives passage to the *facial nerve* and *stylomastoid branch of the posterior auricular artery*.
7. *Superior border* of the petrous part presents a narrow *groove for the superior petrosal sinus* and the margins of the groove give attachment to the *tentorium cerebelli*.
8. *Posterior border* and basilar part of the occipital bone forms a *groove for the inferior petrosal sinus*.
9. *Anterior border* is divided into two parts, a lateral and a medial part; the lateral part joins with the squamous part at the petrosquamosal suture and its medial part articulates with the greater wing of the sphenoid.

Tympanic Part

It is a plate of bone that lies between the squamous and the mastoid parts. In front, it articulates with the squamous part at the *squamotympanic fissure*, and behind, with the mastoid process at the *tympanomastoid fissure*. The tympanomastoid fissure transmits the *auricular branch of the vagus nerve*. Internally, it is fused with the petrous part of the temporal bone.

It presents the following features:

1. *Anterior surface* forms the posterior nonarticular part of the mandibular fossa and lodges a portion of the parotid gland.
2. *Posterior surface* is concave. It forms the anterior and part of the posterior wall and the floor of the external acoustic meatus. The medial part of this surface has a circular *tympanic sulcus*, which gives attachment to the *tympanic membrane*.
3. *Lateral margin* forms the margin of the bony external ear. It gives attachment to the cartilaginous part of the external ear.
4. *Superior border* articulates with the squamous part medially at the *squamotympanic fissure*.
5. *Lower border* extends from the carotid canal to the styloid process. It forms a *sheath of styloid process*.

Styloid Process

Styloid (Greek *pillar form*) process is long pointed process directed downwards, forwards and medially between parotid gland and internal jugular vein (Plate 1.19).

- Its base is related to facial nerve
- Its apex is crossed by external carotid artery
- It gives attachment to three muscles and two ligaments.

SPHENOID BONE

Sphenoid (Greek *wedge*) bone resembles a bat with outstretched wings. It comprises (Plate 1.20):

- A body in the centre.
- Two lesser wings from the anterior part of body.
- Two greater wings from the lateral part of body.
- Two pterygoid (wing-like) processes, directed downwards from the junction of body and greater wings.

BODY OF SPHENOID

It comprises six surfaces and encloses a pair of sphenoidal air sinuses.

Superior or Cerebral Surface

It articulates with ethmoid bone anteriorly and basilar part of occipital bone posteriorly. It shows:

1. Jugum sphenoidale
2. Sulcus chiasmaticus
3. Tuberculum sellae
4. Sella turcica
5. Dorsum sellae
6. Clivus

Inferior Surface

1. Rostrum of sphenoid
2. Sphenoid conchae
3. Vaginal processes of medial pterygoid plate.

Anterior Surface

Sphenoidal crest articulates with perpendicular plate of ethmoid to form a small part of septum of nose.

Opening of sphenoidal air sinus is seen. Sphenoidal conchae close the sphenoid air sinuses leaving the openings. Each half of anterior surface has two parts—superolateral and inferomedial.

The superolateral depression articulates with labyrinth of ethmoid to complete the posterior ethmoidal air sinuses. The inferomedial smooth triangular area forms the posterior part of the root of the nose.

Posterior Surface

It articulates with basilar part of occipital bone.

Lateral Surfaces

Carotid sulcus, a broad groove curved like letter 'f' for lodging cavernous sinus and internal carotid artery. Below the sulcus, it articulates with greater wing of sphenoid laterally and with pterygoid process, which is directed downwards.

Sphenoidal Air Sinuses

These are asymmetrical air sinuses in the body of sphenoid, and are closed by sphenoidal conchae. The sinus opens into the lateral wall of nose in the sphenoethmoidal recess above the superior concha.

GREATER WINGS

These are two strong processes that curve laterally and upwards from the sides of the body. It has three surfaces.

Superior or Cerebral Surface

It forms the floor of middle cranial fossa and presents from before backwards:

1. Foramen rotundum
2. Foramen ovale
3. Emissary sphenoidale foramen
4. Foramen spinosum.

Lateral Surface

A horizontal ridge, the infratemporal crest divides this surface into upper or temporal surface and a lower or infratemporal surface. It is pierced by foramen ovale and foramen spinosum. Its posterior part presents spine of sphenoid.

Orbital Surface

Forms the posterior wall of the lateral wall of orbit. Its medial border bears a small tubercle for attachment of a common tendinous ring for the origin of recti muscles of the eyeball. Below the medial end of superior orbital fissure, the grooved area forms the posterior wall of the pterygopalatine fossa and is pierced by foramen rotundum. Borders are surrounding the greater wing of sphenoid.

LESSER WINGS

Lesser wings are two triangular plates projecting laterally from the anterosuperior part of the body. It comprises:

- A base forming medial end of the wing. It is connected to the body by two roots which enclose the optic canal.
- Tip forms the lateral end of the wing.
- Superior surface forming floor of anterior cranial fossa.
- Inferior surface forming upper boundary of superior orbital fissure.
- Anterior border articulates with the posterior border of orbital plate of frontal bone.
- Posterior border is free and projects into the stem of lateral sulcus of brain. Medially, it terminates into the anterior clinoid process.

Superior Orbital Fissure

It is a triangular gap through which middle cranial fossa communicates with the orbit. The structures passing through it are put in list of foramina and structures passing through them.

PTERYGOID PROCESSES

One pterygoid (Greek *wing*) process on each side projects downwards from the junction of the body with the greater wing of sphenoid (Plate 1.20).

Each pterygoid process divides inferiorly into the medial and lateral pterygoid plates. The plates are fused together in their upper parts, but are separated in their lower parts by the pterygoid fissure. Posteriorly, the pterygoid plates enclose a 'V-shaped interval', the pterygoid fossa. The medial pterygoid plate in its upper part presents a scaphoid fossa. *Refer* to *norma basalis* for medial and lateral pterygoid plates

ETHMOID BONE

Ethmoid (Greek *sieve*) is a very light cuboidal bone situated in the anterior base of cranial cavity between the two orbits (Plate 1.21).

It forms:

1. Part of nasal septum
2. Part of medial wall of orbit
3. Lateral walls of the nasal cavity

Ethmoid bone comprises:

1. Cribriform plate
2. Perpendicular plate
3. A pair of labyrinth

CRIBRIFORM PLATE

It is a horizontal perforated bony lamina, occupying ethmoidal notch of frontal bone. It contains foramina for olfactory nerve rootlets.

Crista Galli

Crista galli is a median, tooth-like upward projection in the floor of anterior cranial fossa. Foramen transmitting anterior ethmoidal nerve to nasal cavity is situated by the side of crista galli.

PERPENDICULAR PLATE

It is a thin lamina projecting downwards from the undersurface of the cribriform plate, forming upper part of nasal septum.

Plate 1.20: Sphenoid bone

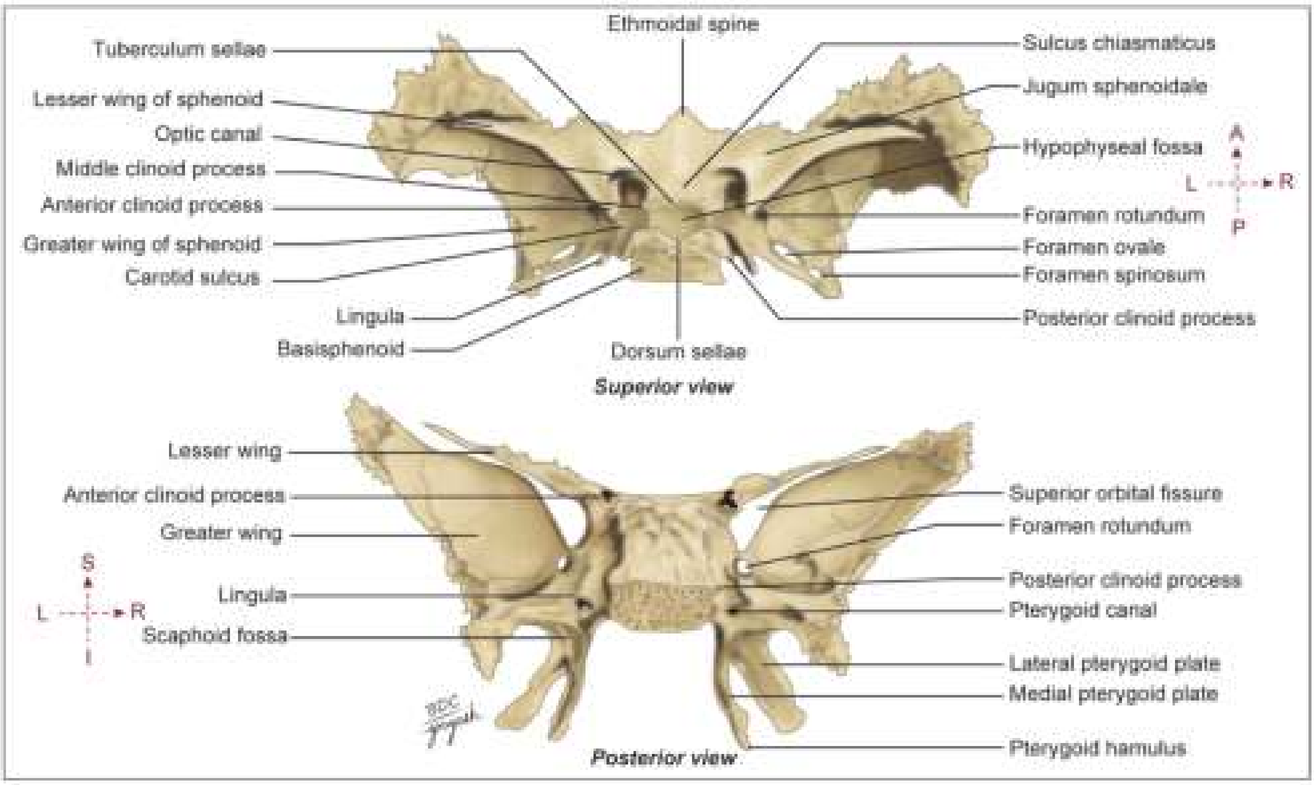
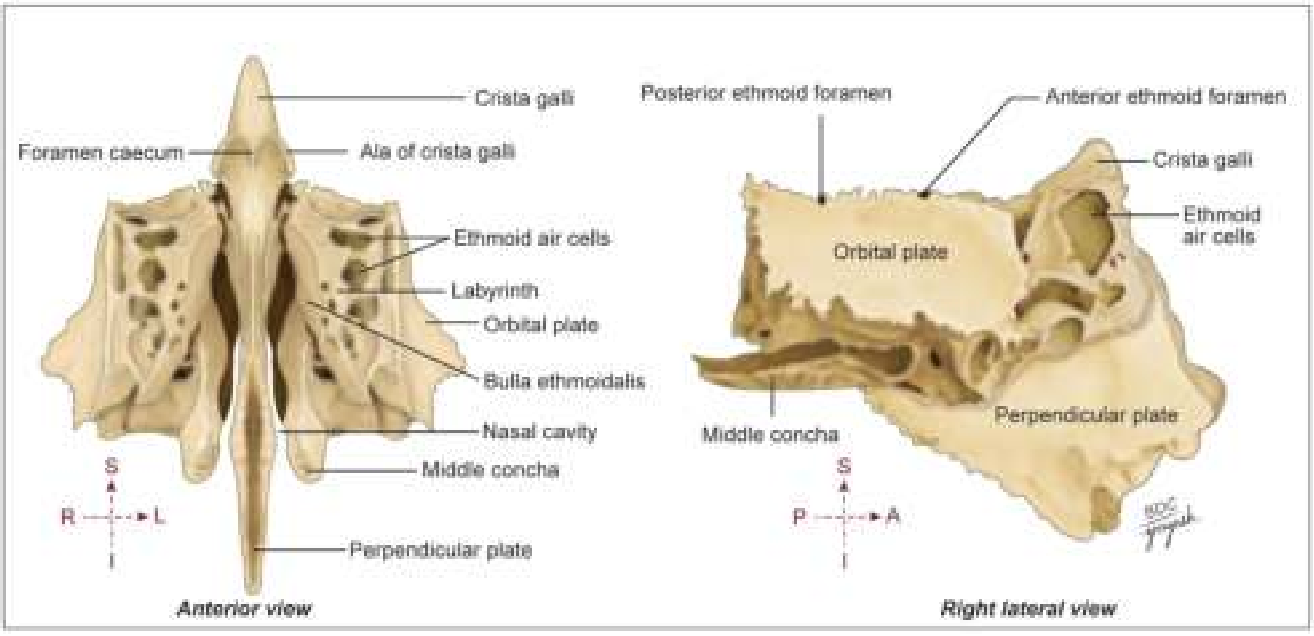

Ethmoidal spine
Tuberculum sellae
Sulcus chiasmaticus
Lesser wing of sphenoid
Jugum sphenoidale
Optic canal
Middle clinoid process
Hypophyseal fossa
A
L
R
P
Anterior clinoid process
Foramen rotundum
Greater wing of sphenoid
Foramen ovale
Carotid sulcus
Foramen spinosum
Lingula
Posterior clinoid process
Basisphenoid
Dorsum sellae
Superior view
Lesser wing
Anterior clinoid process
Superior orbital fissure
Greater wing
Foramen rotundum
S
L
R
I
Lingula
Posterior clinoid process
Scaphoid fossa
Pterygoid canal
Lateral pterygoid plate
Medial pterygoid plate
Posterior view
Pterygoid hamulus

Plate 1.21: Right ethmoid bone


Crista galli
Foramen caecum
Ala of crista galli
Ethmoid air cells
Labyrinth
Orbital plate
Bulla ethmoidalis
Nasal cavity
Middle concha
S
R
L
I
Perpendicular plate
Anterior view
Posterior ethmoid foramen
Anterior ethmoid foramen
Crista galli
Ethmoid air cells
Orbital plate
Perpendicular plate
Middle concha
S
P
A
I
Right lateral view

LABYRINTHS

These are two light cubical masses situated on each side of the perpendicular plate, suspended from the undersurface of the cribriform plate (Plate 1.21). Each labyrinth also encloses large number of 'air cells' arranged in three groups—the anterior, middle and posterior ethmoidal air sinuses. Its surfaces are:

- Anterior surface articulates with frontal process of maxilla to complete anterior ethmoidal air cells.
- Posterior surface articulates with sphenoidal concha to complete posterior ethmoidal air cells.
- Superior surface articulates with orbital plate of frontal bone.
- Inferior surface articulates with nasal surface of maxilla.
- Lateral surface forms medial wall of orbit.
- Medial surface presents small superior nasal concha, middle nasal concha, superior meatus below superior concha and middle meatus below middle concha.

VOMER

Vomer (Latin *plough share*) is a single thin, flat bone forming posteroinferior part of the nasal septum. It comprises:

- Right and left surfaces marked by nasopalatine nerves which course downwards and forwards (Plate 1.22).
- Superior border splits into two alae with a groove occupied by rostrum of sphenoid.
- Inferior border articulates with nasal crests of maxillae and palatine bones.
- Anterior, longest border, articulates with perpendicular plate of ethmoid above and with septal cartilage below.
- Posterior border is free and separates the two posterior nasal openings.

INFERIOR NASAL CONCHAE

The inferior nasal conchae are two curved bony laminae, these are horizontally placed in the lower part of lateral walls of the nose. Between this concha and floor of the nose lies the inferior meatus of the nose. It comprises two surfaces, two borders and two ends.

- Medial convex surface is marked by vascular grooves.
- Lateral concave surface forms the medial wall of inferior meatus of the nose.
- Superior border is irregular and articulates with lacrimal, maxilla, ethmoid and palatine bones (Plate 1.23).
- Inferior border is free, thick and spongy.
- Posterior end is more pointed than the anterior end.

ZYGOMATIC BONES

These are two small quadrilateral bones present in the upper and lateral part of face. The bone forms prominence of the cheeks. Each bone takes part in the formation of (Plate 1.24):

- Floor and lateral wall of the orbit
- Walls of temporal and infraorbital fossae.

Zygomatic bone comprises three surfaces, four borders and two processes.

Surfaces

1. Lateral surface presenting zygomaticofacial foramen.
2. Temporal surface is smooth and concave and presents zygomaticotemporal foramen.
3. Orbital surface is also smooth and concave with one or two zygomatico-orbital foramen on this surface and this leads to zygomaticofacial and zygomaticotemporal foramina.

Borders

1. Anterosuperior or orbital
2. Anteroinferior or maxillary
3. Posterosuperior or temporal border
4. Posteroinferior border

Plate 1.22: Right vomer

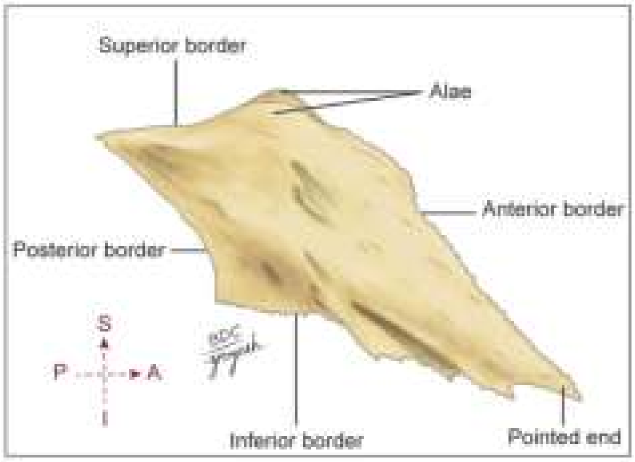
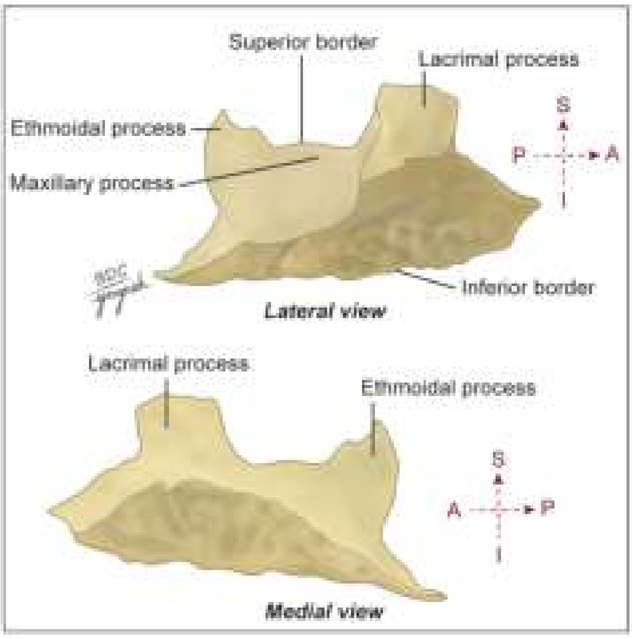


Plate 1.23: Right inferior nasal concha



Processes

1. Frontal process, which is directed upwards.
2. Temporal process, which is directed backwards.

NASAL BONES

Nasal bones are two small oblong bones, which form the bridge of the nerve.

Each nasal bone has two surfaces and four borders (Plate 1.25).

Surfaces

1. The outer surface is convex from side-to-side.
2. The inner surface is concave from side-to-side and is traversed by a vertical groove for anterior ethmoidal nerve.

Borders

1. Superior border is thick and serrated and articulates with nasal part of frontal bone.

Plate 1.24: Right zygomatic bone

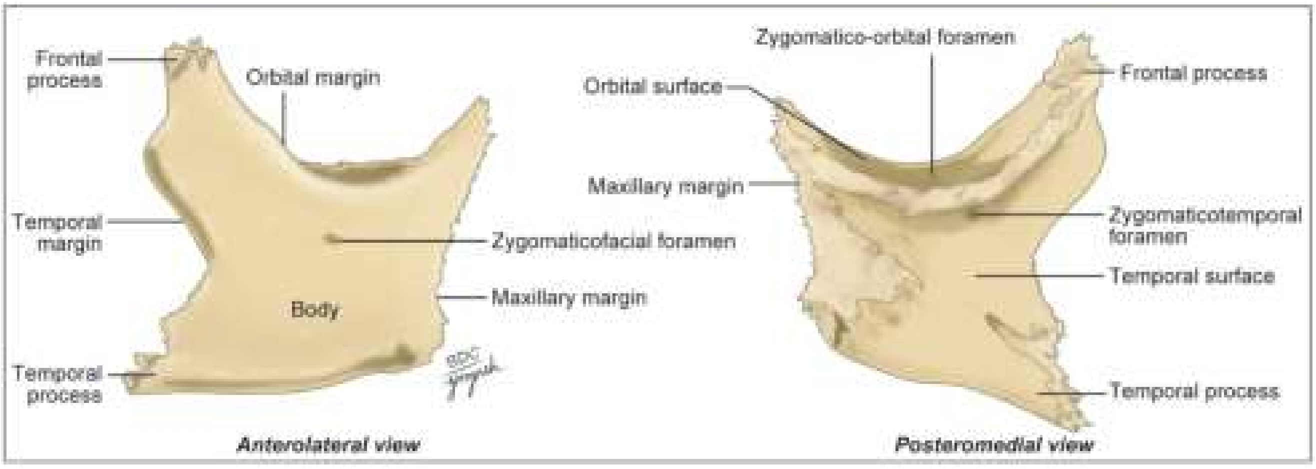
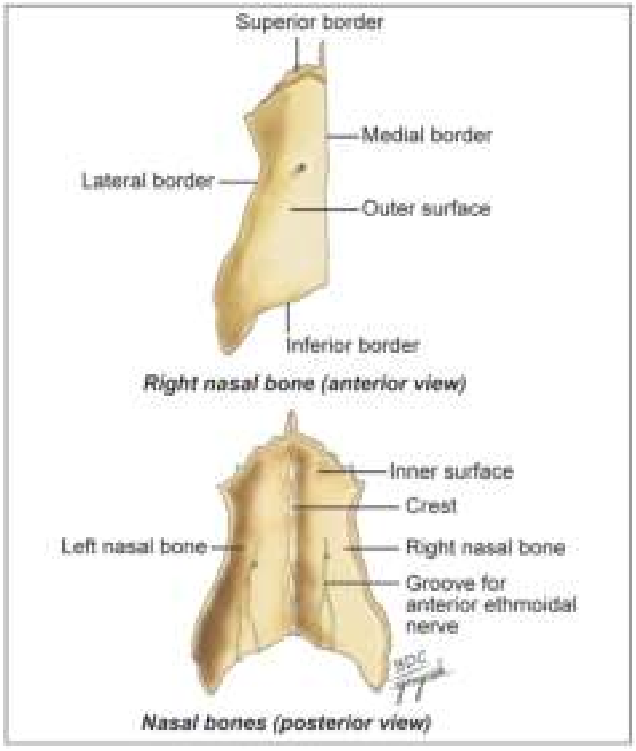

Frontal process
Orbital margin
Temporal margin
Zygomaticofacial foramen
Body
Maxillary margin
Temporal process
Anterolateral view
Zygomatico-orbital foramen
Orbital surface
Frontal process
Maxillary margin
Zygomaticotemporal foramen
Temporal surface
Temporal process
Posteromedial view
SDC

Plate 1.25: Nasal bones

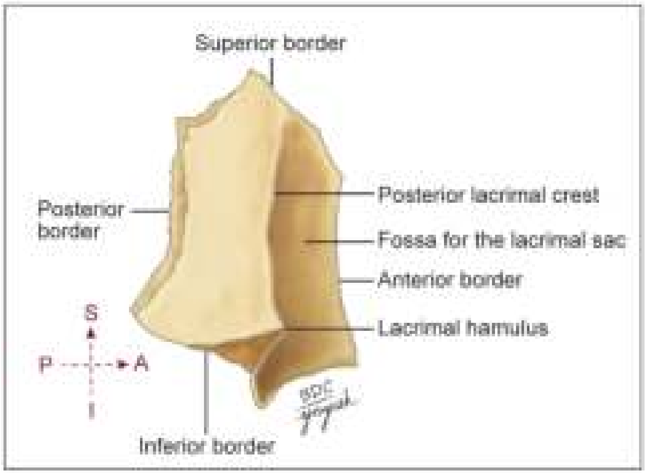

Superior border
Medial border
Lateral border
Outer surface
Inferior border
Right nasal bone (anterior view)
Inner surface
Crest
Left nasal bone
Right nasal bone
Groove for anterior ethmoidal nerve
Nasal bones (posterior view)
SDC

2. Inferior border is thin and notched and articulates with superior nasal cartilage.
3. Medial border articulates with opposite nasal bone.
4. Lateral border articulates with frontal process of maxilla.

LACRIMAL BONES

Lacrimal bones are extremely delicate and smallest of the skull bones. These form the anterior part of the medial part of the orbit. Each lacrimal bone comprises two surfaces and four borders (Plate 1.26)

Plate 1.26: Right lacrimal bone (lateral view)


Superior border
Posterior border
Posterior lacrimal crest
Fossa for the lacrimal sac
Anterior border
Lacrimal hamulus
S
P
A
I
Inferior border
SDC

Surfaces

1. Lateral or orbital surface is divided by posterior lacrimal crest into anterior and posterior parts. The anterior grooved part forms posterior half of the floor of lacrimal groove for lacrimal sac. The posterior smooth part forms part of medial wall of orbit.
2. Medial or nasal surface forms a part of middle meatus of the nose.

Borders

1. Anterior border articulates with frontal process of maxilla.
2. Posterior border with orbital plate of ethmoid.
3. Superior border with frontal bone.
4. Inferior border with orbital surface of maxilla.

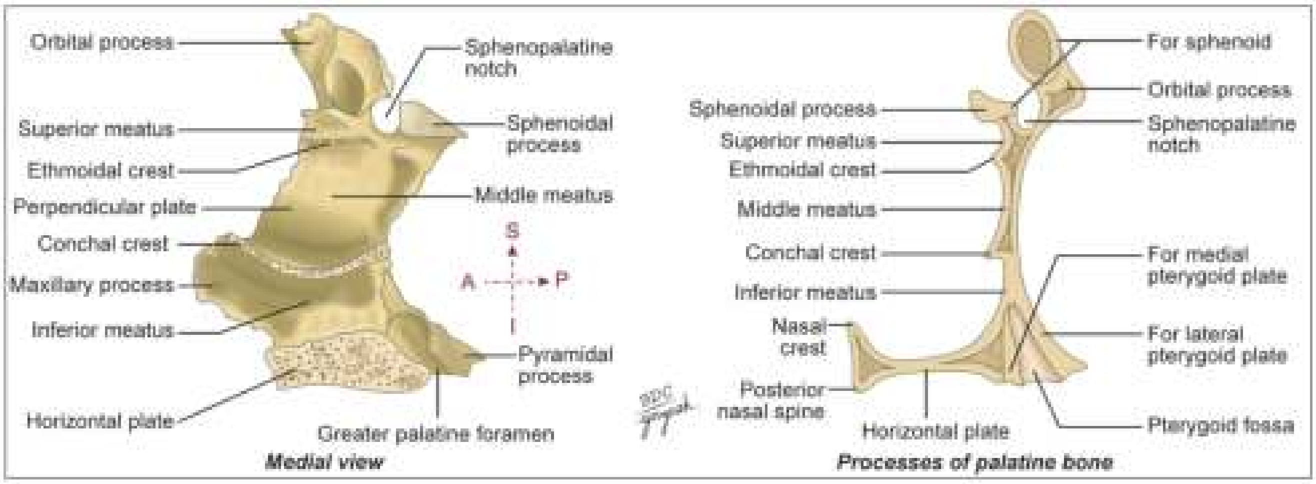
PALATINE BONES

Palatine bones are two L-shaped bones present in the posterior part of nasal cavity. Each bone forms:

- Lateral wall and floor of nasal cavity (Plate 1.27).
- Roof of mouth cavity
- Floor of the orbit
- Parts of pterygopalatine fossa.

Each palatine bone has two plates and three processes.

Plate 1.27: Right palatine bone


Orbital process
Superior meatus
Ethmoidal crest
Perpendicular plate
Conchal crest
Maxillary process
Inferior meatus
Horizontal plate
Sphenopalatine notch
Sphenoidal process
Middle meatus
S
A
P
I
Pyramidal process
Greater palatine foramen
Medial view
Sphenoidal process
Superior meatus
Ethmoidal crest
Middle meatus
Conchal crest
Inferior meatus
Nasal crest
Posterior nasal spine
Horizontal plate
For sphenoid
Orbital process
Sphenopalatine notch
For medial pterygoid plate
For lateral pterygoid plate
Pterygoid fossa
Processes of palatine bone

Plates

1. Horizontal plate forms posterior one-fourth part of bony palate. It has two surfaces and four borders.
2. Perpendicular plate of palatine bone is oblong in shape and comprises two surfaces and four borders *(refer to norma basalis)*.

Processes

Pyramidal

Pyramidal process projects downwards from the junction of two plates. Its inferior surface is pierced by lesser palatine foramina.

Orbital

Orbital process projects upwards and laterally from the perpendicular plate. Its orbital surface is triangular and forms the posterior part of the floor of the orbit.

Sphenoidal

Sphenoidal process projects upwards and medially from the perpendicular plate. Its lateral surface articulates with medial pterygoid plate.

HYOID BONE

The hyoid (Greek *U-shaped*) bone is U-shaped. It is situated in the anterior midline of the neck between the chin and the thyroid cartilage (Plate 1.28, Flowchart 1.15).

At rest, it lies at the level of the 3rd cervical vertebra behind and the base of the mandible in front.

It is kept suspended in position by muscles and ligaments.

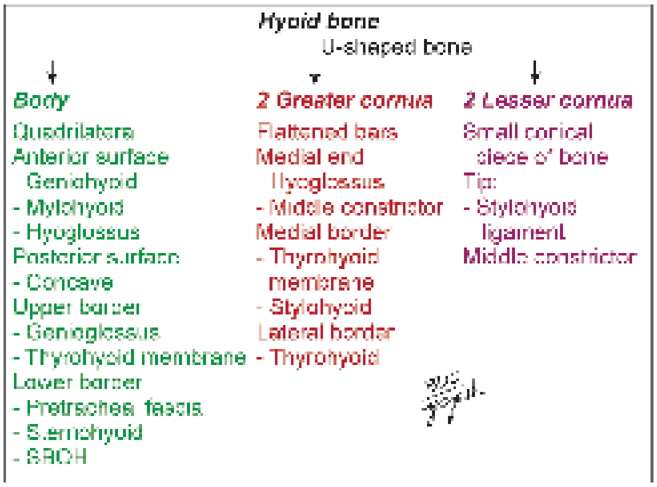
The hyoid bone provides attachment to the muscles of the floor of the mouth and to the tongue above, to the larynx below and to the epiglottis and pharynx behind (Fig. 1.27).

Parts of Hyoid Bone

The hyoid bone consists of the following parts (Plate 1.28, Fig. 1.27):

1. Body
2. Pair of greater cornua
3. Pair of lesser cornua

Flowchart 1.15: Hyoid bone



Hyoid bone

U-shaped bone

Body
Quadrilateral
Anterior surface
Geniohyoid
- Mylohyoid
- Hyoglossus
Posterior surface
- Concave
Upper border
- Genioglossus
- Thyrohyoid membrane
Lower border
- Pretracheal fascia
- Sternohyoid
- SBOH

2 Greater cornua
Flattened bars
Medial end
Hyoglossus
- Middle constrictor
Medial border
- Thyrohyoid membrane
- Stylohyoid
Lateral border
- Thyrohyoid

2 Lesser cornua
Small conical piece of bone
Tip:
- Stylohyoid ligament
Middle constrictor

(SBOH: Superior belly of omohyoid)

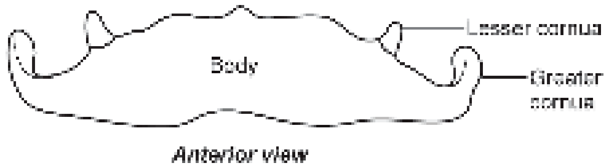

Lesser cornua
Body
Greater cornua
Anterior view

Fig. 1.27: Features of hyoid bone

Body

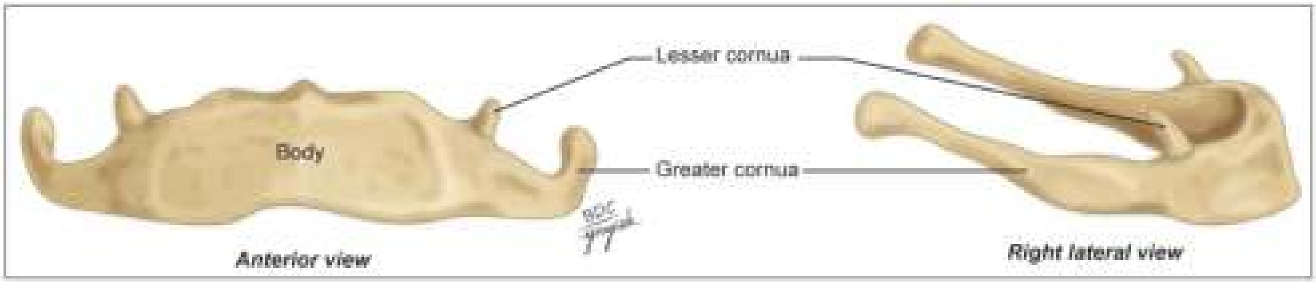
It has two surfaces—anterior and posterior, and two borders—upper and lower.

The *anterior surface* is convex and is directed forwards and upwards. It is often divided by a median ridge into two lateral halves.

The *posterior surface* is concave and is directed backwards and downwards.

Each lateral end of the body is continuous posteriorly with the greater horn or cornua. However, till middle life, the connection between the body and greater cornua is fibrous.

Plate 1.28: Hyoid bone



Greater Cornua

These are flattened from above downwards. Each cornua tapers posteriorly but ends in a tubercle. It has two surfaces—upper and lower, two borders—medial and lateral and a tubercle.

Lesser Cornua

These are small conical pieces of bone that project upwards from the junction of the body and greater cornua. The lesser cornua are connected to the body by fibrous tissue. Occasionally, they are connected to the greater cornua by synovial joints, which usually persist throughout life but may get ankylosed.

ATTACHMENTS ON THE HYOID BONE

1. Anterior surface of the body provides insertion to the geniohyoid and mylohyoid muscles and gives origin to a part of the hyoglossus, which extends to the greater cornua (Fig. 1.28).
2. *Upper border* of the body provides insertion to the lower fibres of the genioglossi and attachment to the thyrohyoid membrane.
3. *Lower border* of the body provides attachment to the pretracheal fascia. In front of the fascia, the *sternohyoid* is inserted medially and the superior belly of omohyoid laterally.
4. Below the omohyoid, there is the linear attachment of the thyrohyoid, extending back to the lower border of the greater cornua.

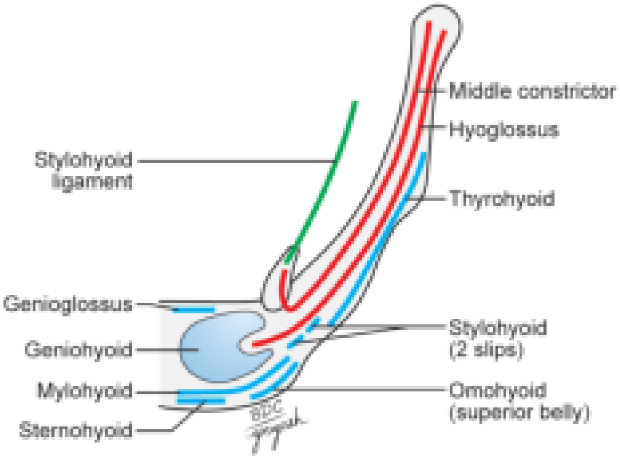


Fig. 1.28: Attachments of the hyoid bone

5. *Medial border* of the greater cornua provides attachment to the thyrohyoid membrane, two slips each of stylohyoid muscle and digastric pulley.
6. *Lateral border* of the greater cornua provides insertion to the thyrohyoid muscle anteriorly. The investing fascia is attached throughout its length.
7. The lesser cornua provides attachment to the stylohyoid ligament at its tip. The middle constrictor muscle arises from its posterolateral aspect extending onto the greater cornua.

DEVELOPMENT

Upper part of body and lesser cornua develop from 2nd branchial arch, while lower part of body and greater cornua develop from the 3rd arch.

CLINICAL ANATOMY

- Hyoid fractures are common in throttling and strangulation.
- Palpation of greater cornua of hyoid bone: It can be palpated in the relaxed neck, at the anterior border of sternocleidomastoid muscle, midway between the mastoid process and the laryngeal prominence.

Competency:
AN26.5 Describe features of typical and atypical cervical vertebrae (atlas and axis).

CERVICAL VERTEBRAE

IDENTIFICATION

The cervical vertebrae are identified by the presence of foramina transversaria.

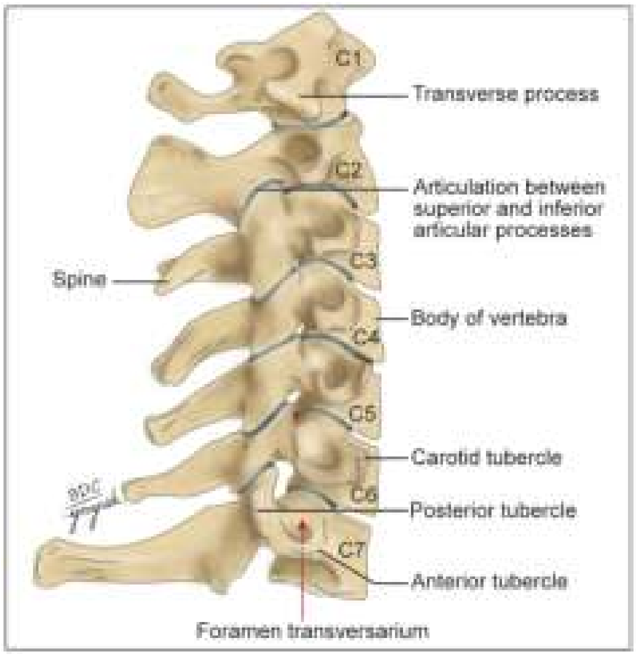
There are seven cervical vertebrae, out of which the 3rd to 6th are ***typical***, while the 1st, 2nd and 7th are ***atypical*** (Plate 1.29).

TYPICAL CERVICAL VERTEBRAE

Body

1. The body is *small* and *broader* from side-to-side than from before backwards.

Plate 1.29: Articulated cervical vertebrae (right lateral view)


C1
Transverse process
C2
Articulation between superior and inferior articular processes
Spine
C3
Body of vertebra
C4
C5
Carotid tubercle
C6
Posterior tubercle
C7
Anterior tubercle
Foramen transversarium

2. Its *superior surface* is concave transversely with upward projecting lips on each side. The anterior border of this surface may be bevelled.
3. The *inferior surface* is saddle-shaped, being convex from side-to-side and concave from before backwards. The lateral borders are bevelled and form synovial joints with the projecting lips of the next lower vertebra. The anterior border projects downwards and may hide the intervertebral disc.
4. The *anterior and posterior surfaces* resemble those of other vertebrae (Plate 1.30, Fig. 1.29, Flowchart 1.16).

Vertebral Foramen

Vertebral foramen is larger than the body. It is triangular in shape because the pedicles are directed backwards and laterally.

Vertebral Arch

1. ***Pedicles*** are directed backwards and laterally. The superior and inferior vertebral notches are of equal size.
2. ***Laminae*** are relatively long and narrow, being thinner above than below.
3. The *superior and inferior articular processes* form articular pillars, which project laterally at the junction of pedicle and the lamina. The superior articular facets are flat. They are directed backwards and upwards. The inferior articular facets are also flat but are directed forwards and downwards.
4. The ***transverse processes*** are pierced by foramina transversaria. Each process has *anterior* and *posterior roots*, which end in tubercles joined by the *costotransverse bar*.

   Note: The ***costal element*** is represented by the *anterior root, anterior tubercle, the costotransverse bar and the posterior tubercle*. Posterior root represents the transverse process.

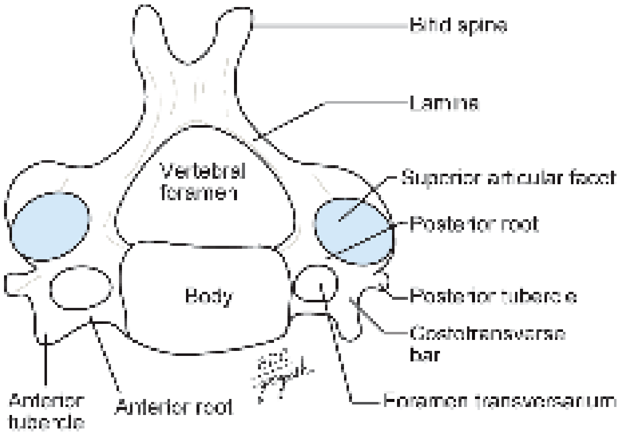
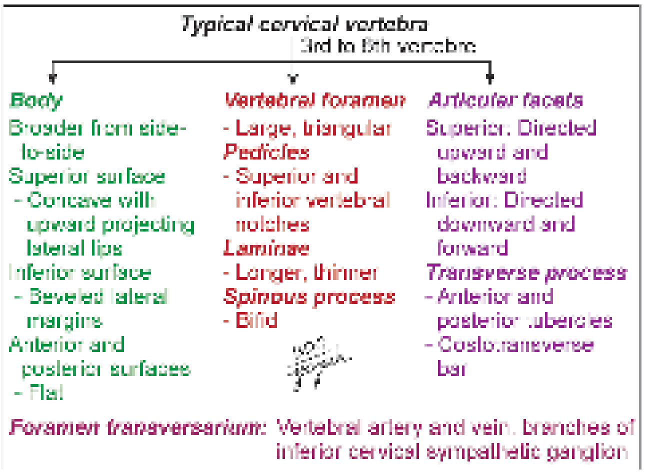

Bifid spine
Lamina
Vertebral foramen
Superior articular facet
Posterior root
Body
Posterior tubercle
Costotransverse bar
Anterior tubercle
Anterior root
Foramen transversarium

Fig. 1.29: Typical cervical vertebra seen from above

Flowchart 1.16: Typical cervical vertebra



Typical cervical vertebra
3rd to 6th vertebra

Body
Broader from side-to-side
Superior surface
- Concave with upward projecting lateral lips
Inferior surface
- Beveled lateral margins
Anterior and posterior surfaces
- Flat

Vertebral foramen
- Large, triangular
Pedicles
- Superior and inferior vertebral notches
Laminae
- Longer, thinner
Spinous process
- Bifid

Articular facets
Superior: Directed upward and backward
Inferior: Directed downward and forward
Transverse process
- Anterior and posterior tubercles
- Costotransverse bar

Foramen transversarium: Vertebral artery and vein, branches of inferior cervical sympathetic ganglion

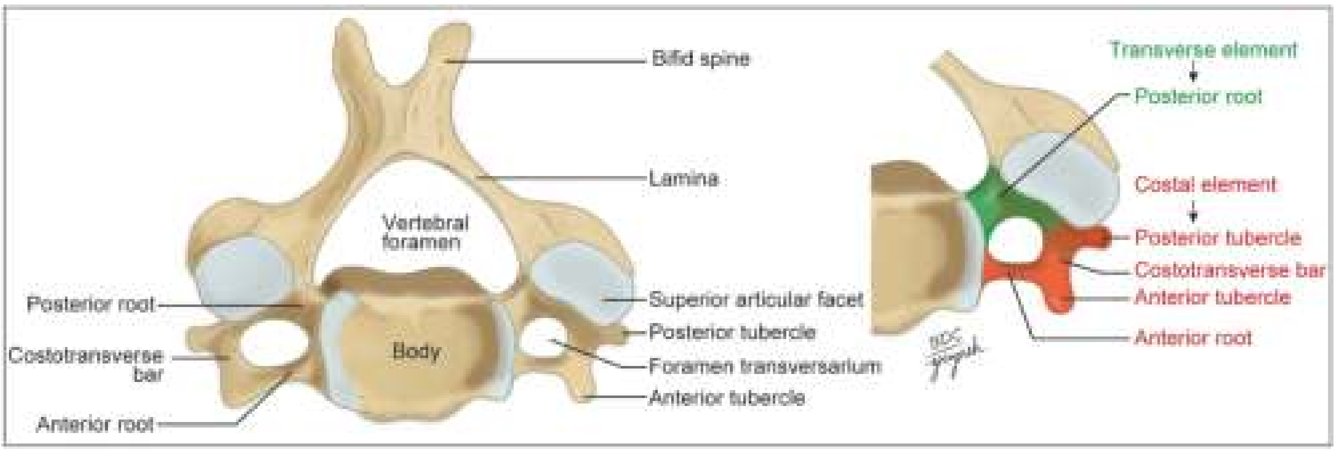
The anterior tubercle of the 6th cervical vertebra is large and is called the ***carotid tubercle*** because the common carotid artery can be compressed against it.

5. ***Spine*** is short and bifid. The notch is filled up by the ligamentum nuchae.

Attachments and Relations

1. The anterior and posterior longitudinal ligaments are attached to the upper and lower borders of the body in front and behind, respectively. On each side of the anterior longitudinal ligament, the vertical part of the longus colli is attached to the anterior surface. The posterior surface has two or more foramina for passage of *basivertebral veins*.
2. The upper borders and lower parts of the anterior surfaces of the laminae provide attachment to the ligamenta flava.
3. The *foramen transversarium* transmits the *vertebral artery*, the *vertebral veins* and a *branch from the inferior cervical ganglion*. The *anterior tubercles* give origin to the scalenus anterior, the longus capitis and the oblique part of the longus colli.
4. The *costotransverse bars* are grooved by the *anterior primary rami* of the corresponding cervical nerves.
5. The *posterior tubercles* give origin to the scalenus medius, scalenus posterior, levator scapulae. The

Plate 1.30: Typical cervical vertebra (4th cervical vertebra)


Bifid spine
Lamina
Vertebral foramen
Posterior root
Costotransverse bar
Body
Anterior root
Superior articular facet
Posterior tubercle
Foramen transversarium
Anterior tubercle
Transverse element
Posterior root
Costal element
Posterior tubercle
Costotransverse bar
Anterior tubercle
Anterior root

splenius cervicis, the longissimus cervicis and the iliocostalis cervicis are inserted into posterior tubercles.

6. The spine gives origin to the deep muscles of the back of the neck—spinalis cervicis, semispinalis cervicis and thoracis and multifidus.

OSSIFICATION

A typical cervical vertebra ossifies from three primary and six secondary centres.

There is one *primary centre* for each half of the neural arch during 9 to 10 weeks of foetal life and one for the *centrum* in 3 to 4 months of foetal life. The two halves of the neural arch fuse posteriorly with each other during the 1st year. Synostosis at the neurocentral synchondrosis occurs during the 3rd year.

The *secondary centres*, *two* for the annular epiphyseal discs for the peripheral parts of the upper and lower surfaces of the body, *two* for the tips of the transverse processes and *two* for the bifid spine, appear during puberty and fuse with the rest of the vertebrae by 25 years.

FIRST CERVICAL VERTEBRA

It is called the ***atlas*** (Tiltan, who supported the heaven).

It can be identified by the following features:

1. It is ring-shaped. It has neither a body nor a spine (Plate 1.31, Figs 1.30 and 1.31, Flowchart 1.17).
2. The atlas has a short anterior arch, a long posterior arch, right and left lateral masses and transverse processes.
3. ***Anterior arch*** is marked by a median *anterior tubercle* on its anterior aspect. Its posterior surface bears an *oval facet* that articulates with the *dens.*
4. ***Posterior arch*** forms about 2/5th of the ring and is much longer than the anterior arch. Its posterior surface is marked by a median posterior tubercle. The upper surface of the arch is marked behind the lateral mass by a *groove*. Each *lateral mass* shows the following important features.

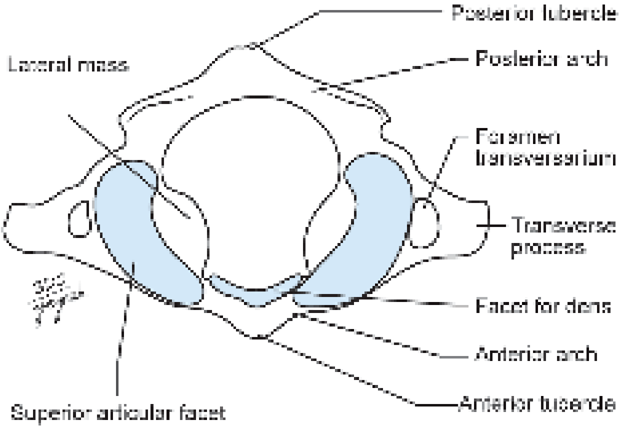

Posterior tubercle
Posterior arch
Lateral mass
Foramen transversarium
Transverse process
Facet for dens
Anterior arch
Anterior tubercle
Superior articular facet

Fig. 1.30: Atlas vertebra

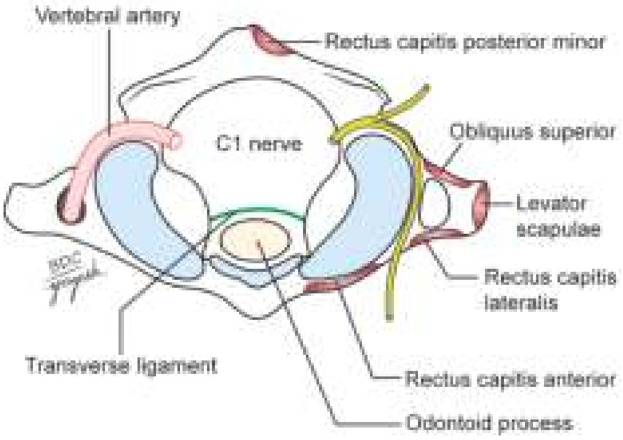
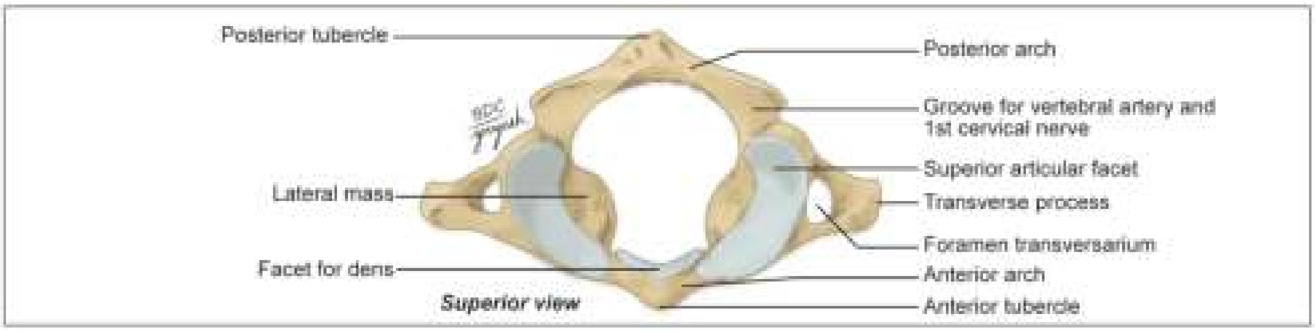

Vertebral artery
Rectus capitis posterior minor
C1 nerve
Obliquus superior
Levator scapulae
Rectus capitis lateralis
Transverse ligament
Rectus capitis anterior
Odontoid process

Fig. 1.31: Relations of atlas vertebra

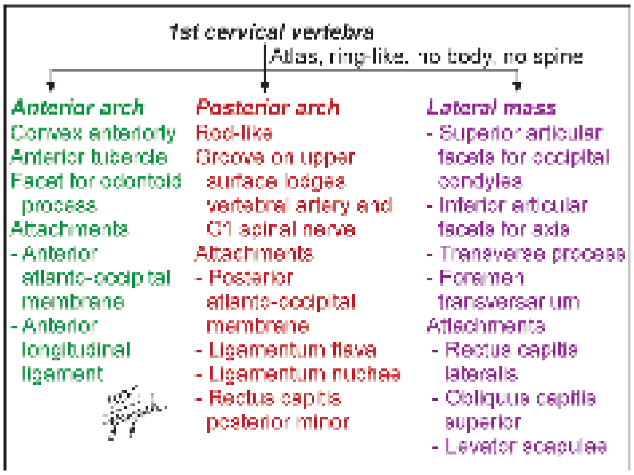
a. Its upper surface bears the *superior articular facet.* This facet is elongated (forwards and medially), concave and is directed upwards and medially. It articulates with the corresponding condyle of the occipital bone to form an atlanto-occipital joint.

b. The lower surface is marked by the *inferior articular facet*. This facet is nearly circular, more or less flat and is directed downwards, medially and backwards. It articulates with

Plate 1.31: Atlas vertebra


Posterior tubercle
Posterior arch
Groove for vertebral artery and 1st cervical nerve
Superior articular facet
Lateral mass
Transverse process
Foramen transversarium
Facet for dens
Anterior arch
Superior view
Anterior tubercle

Flowchart 1.17: 1st cervical vertebra


1st cervical vertebra
Atlas, ring-like, no body, no spine
Anterior arch
Convex anteriorly
Anterior tubercle
Facet for odontoid process
Attachments
- Anterior atlanto-occipital membrane
- Anterior longitudinal ligament
Posterior arch
Rod-like
Groove on upper surface lodges vertebral artery and C1 spinal nerve
Attachments
- Posterior atlanto-occipital membrane
- Ligamentum flava
- Ligamentum nuchea
- Rectus capitis posterior minor
Lateral mass
- Superior articular facets for occipital condyles
- Inferior articular facets for axis
- Transverse process
- Foramen transversarium
Attachments
- Rectus capitis lateralis
- Obliquus capitis superior
- Levator scapulea

the corresponding facet on the axis vertebra to form an atlantoaxial joint.

c. The medial surface of the lateral mass is marked by a small roughened tubercle.

d. The *transverse process* projects laterally from the lateral mass. The transverse process is pierced by the foramen transversarium.

Attachments and Relations (Fig. 1.31)

1. The anterior tubercle provides attachment (in the median plane) to the anterior longitudinal ligament, and provides insertion on each side to the upper oblique part of longus colli.
2. The upper border of the anterior arch gives attachment to the anterior atlanto-occipital membrane.
3. The lower border of the anterior arch gives attachment to the lateral fibres of the anterior longitudinal ligament.
4. The posterior tubercle provides attachment to the ligamentum nuchae in the median plane and gives origin to the rectus capitis posterior minor on each side.
5. The groove on the upper surface of the posterior arch is occupied by the *vertebral artery* and by the *first cervical nerve*. Behind the groove, the upper border of the posterior arch gives attachment to the posterior atlanto-occipital membrane.
6. The lower border of the posterior arch gives attachment to the highest pair of ligamenta flava.
7. The tubercle on the medial side of the lateral mass gives attachment to the transverse ligament of the atlas.
8. The anterior surface of the lateral mass gives origin to the rectus capitis anterior.
9. The transverse process gives origin to the rectus capitis lateralis from its upper surface anteriorly, obliquus capitis superior from its upper surface posteriorly, levator scapulae from its lateral margin and lower border and insertion to obliquus capitis inferior from its lower surface of the tip. Its posterior tubercle gives insertion to splenius cervicis.

OSSIFICATION

Atlas ossifies from three centres, one for each lateral mass with half of the posterior arch, one for the anterior arch. The centres for the lateral masses appear during 7th week of intrauterine life and unite posteriorly at about 3 years. The centre for anterior arch appears at about 1st year and unites with the lateral mass at about 7 years.

SECOND CERVICAL VERTEBRA

This is called the *axis* (Latin *axile*). It is identified by the presence of the dens or *odontoid* (Greek *tooth*) process, which is a strong, tooth-like process projecting upwards from the body. The dens is usually believed to represent the centrum or body of the atlas, which has fused with the centrum of the axis (Plate 1.32, Fig. 1.32).

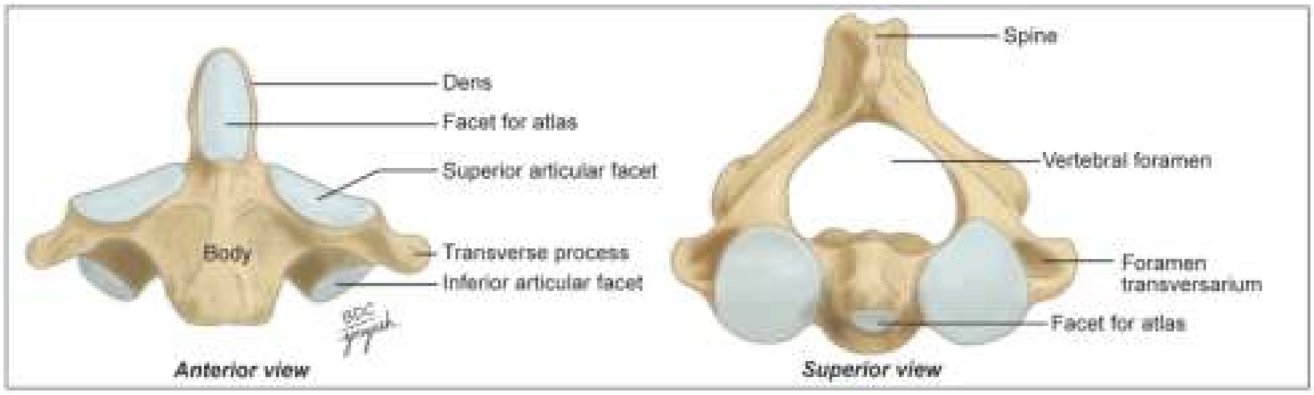
Body and Dens

1. The *superior surface* of the body is fused with the ***dens*** and is encroached upon on each side by the superior articular facets. The dens articulates anteriorly with oval fact on posterior surface of the anterior arch of the atlas, and posteriorly with the transverse ligament of the atlas.
2. The *inferior surface* has a prominent anterior margin, which projects downwards.
3. The *anterior surface* presents a median ridge on each side of which there are hollowed-out impressions.

Vertebral Arch

1. The ***pedicles*** are concealed superiorly by the superior articular processes. The inferior surface presents a deep

Plate 1.32: Axis vertebra



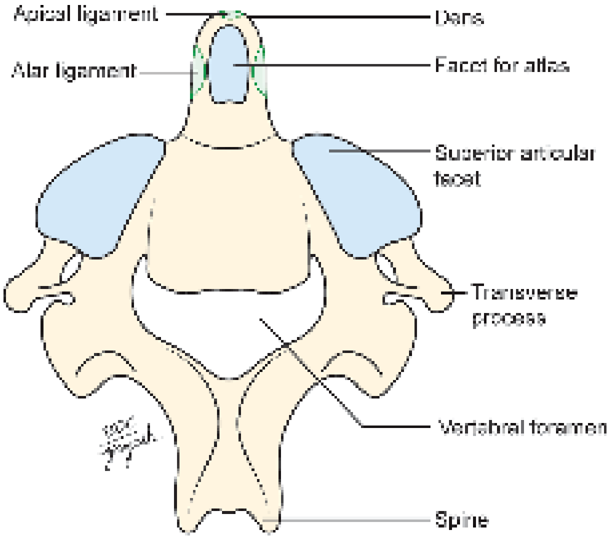


Fig. 1.32: Axis vertebra

and wide *inferior vertebral notch*, placed in front of the inferior articular process. The superior vertebral notch is very shallow and is placed on the upper border of the lamina, behind the superior articular process.

2. The ***laminae*** are thick and strong.
3. ***Articular facets***: Each *superior articular facet* occupies the upper surfaces of the body and of the massive pedicle. Laterally, it overhangs the foramen transversarium. It is a large, flat, circular facet that is directed upwards and laterally. It articulates with the inferior facet of the atlas vertebra to form the atlantoaxial joint. Each *inferior articular facet* lies posterior to the transverse process and is directed downwards and forwards to articulate with the third cervical vertebra.
4. The ***transverse processes*** are very small and represent the true posterior tubercles only. The foramen transversarium is directed upwards and laterally.
5. The ***spine*** is large, thick and very strong. It is deeply grooved inferiorly. Its tip is bifid, terminating in two rough tubercles.

Attachments

1. The dens provides attachment at its apex to the apical ligament, and on each side, below the apex to the alar ligaments.
2. The anterior surface of the body receives the insertion of the longus colli. The anterior longitudinal ligament is also attached to the anterior surface.
3. The posterior surface of the body provides attachment, from below upwards, to the (A) posterior longitudinal ligament, (B) the membrana tectoria and (C) the vertical limb of the cruciate ligament.
4. The laminae provide attachment to the ligamenta flava.
5. The transverse process gives origin by its tip to the levator scapulae, the scalenus medius anteriorly and the splenius cervicis posteriorly. The *intertransverse muscles* are attached to the upper and lower surfaces of the process.
6. The spine gives attachment to the ligamentum nuchae, the semispinalis cervicis, the spinalis cervicis, the interspinalis and the multifidus and origin to rectus capitis posterior major and the obliquus capitis inferior.

***Competency*:**
AN26.7 Describe the features of the 7th cervical vertebra.

SEVENTH CERVICAL VERTEBRA

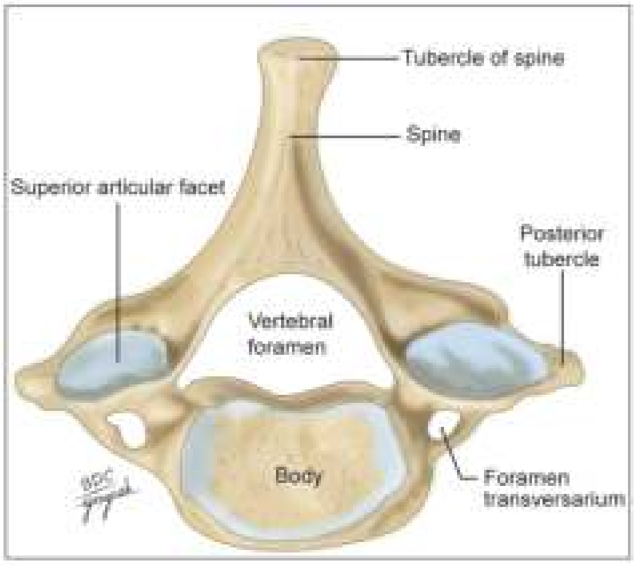
It is also known as the ***vertebra prominens*** because of its long spinous process, the tip of which can be felt through the skin at the lower end of the nuchal furrow. Its spine is thick, long and nearly horizontal. It is not bifid but ends in a tubercle (Plate 1.33).

The transverse processes are comparatively large in size, the posterior root is larger than the anterior. The anterior tubercle is absent. The foramen transversarium is relatively small, sometimes double, or may be entirely absent. It does not transmit the vertebral artery.

Attachments

1. The tip of the *spine* provides attachment to the ligamentum nuchae, trapezius, rhomboid minor, serratus posterior superior, splenius capitis, spinalis cervicis, semispinalis thoracis, interspinales and the multifidus.
2. *Transverse process:* The *foramen transversarium* usually transmits only an accessory vertebral vein. The *posterior tubercle* provides attachment to the

Plate 1.33: C7 vertebra



suprapleural membrane. The lower *border* provides attachment to the first pair of levatores costarum.

3. The anterior root of the transverse process may sometimes be separate. It then forms a *cervical rib* of variable size.

OSSIFICATION

Its ossification is similar to that of a typical cervical vertebra. In addition, separate centre for each costal process appears during 6th month of intrauterine life and fuses with the body and transverse process during 5th to 6th years of life.

CLINICAL ANATOMY

- The costal element of 7th cervical vertebra may get enlarged to form a ***cervical rib*** (Fig. 1.33). A cervical rib is an additional rib arising from the C7 vertebra and usually gets attached to the 1st rib near the insertion of scalenus anterior. If the rib is more than 5 cm long, it usually displaces the brachial plexus and the subclavian artery upwards. The symptoms are tingling pain along the inner border of the forearm and hand including weakness and even paralysis of the muscles of the palm.
- The intervertebral foramina of the cervical vertebrae lie anterior to the joints between the articular processes. Arthritic changes in these joints, if occur, cause tiny projections or osteophytes. These osteophytes may press on the anteriorly placed cervical spinal nerves in the foramina causing pain along the course and distribution of these nerves.
- The joints in the lateral parts of adjacent bodies of cervical vertebrae are called Luschka's joints. The intervertebral foramen lies between Luschka's joints and facet joints. The cervical nerve roots may get pressed by osteophytes in these joints causing pain (Fig. 1.34).
- The vertebral artery coursing through the foramen transversarium lies lateral to Luschka's joints. The osteophytes of Luschka's joints may cause distortion of the vertebral artery leading to vertebrobasilar insufficiency. This may cause vertigo, dizziness, etc.
- Prolapse of the intervertebral disc occurs at the junction of different curvatures. So, the common site is lower cervical and upper lumbar vertebral regions. In the cervical region, the disc involved is above or below 6th cervical vertebra. The nerve roots affected are C6 and C7. There is pain and numbness along the lateral side of forearm and hand. There may be wasting of muscles of thenar eminence.
- During judicial hanging, the odontoid process usually breaks to hit upon the vital centres in the medulla oblongata (Fig. 1.35).
- Atlas may fuse with the occipital bone. This is called *occipitalisation of atlas* and this may at times compress the spinal cord, which requires surgical decompression.
- The pharyngeal and retropharyngeal inflammations may cause decalcification of atlas vertebra. This may lead to loosening of the attachments of transverse ligament, which may eventually yield, causing *sudden death* from *dislocation of dens*.

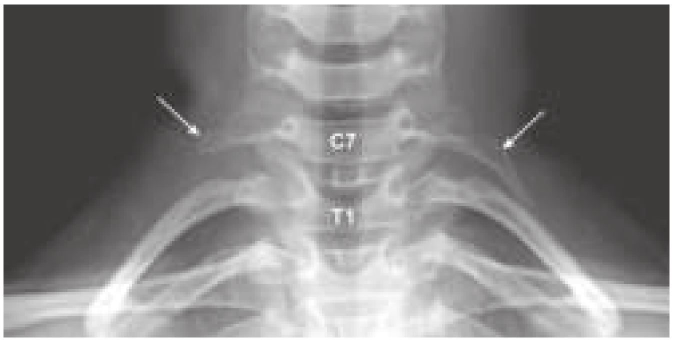


Fig. 1.33: Bilateral cervical ribs

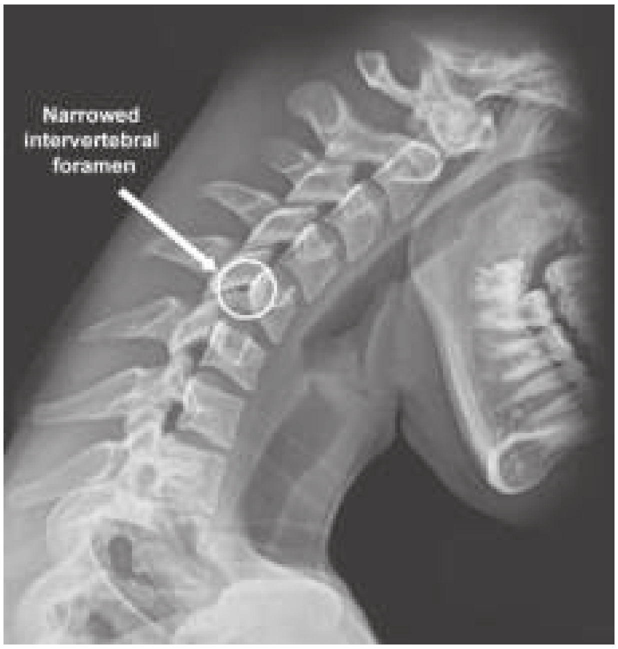


Fig. 1.34: Pressure on the cervical nerve due to bony changes

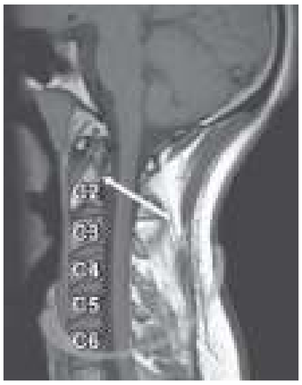


Fig. 1.35: Fracture of the odontoid process during hanging (fracture marked by arrow)

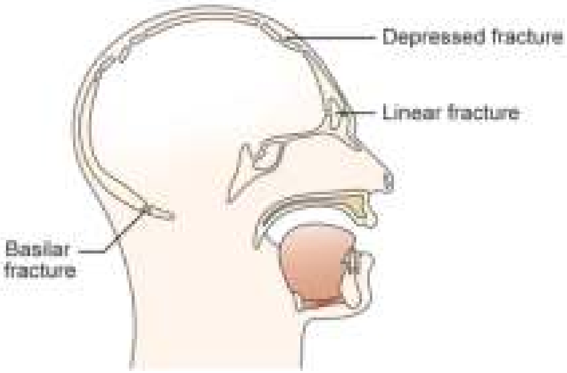


Fig. 1.36: Types of fracture of the skull

- Fractures of skull may be depressed, linear and basilar (Fig. 1.36).
- Hangman's fracture occurs due to fracture of the pedicles of axis vertebra. As the vertebral canal gets enlarged, the spinal cord does not get pressed.

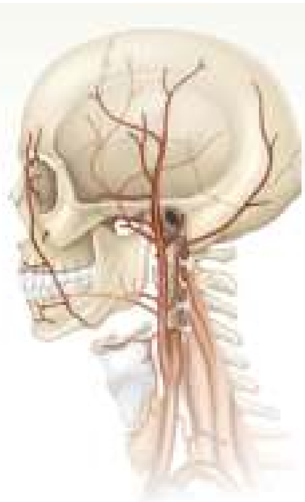
Video 3.1 **Bones of Skull:** Introduction, Bones of skull, Anterior cranial fossa, Middle cranial fossa, Posterior cranial fossa, Orbit, Mandible, Foramina, Norma frontalis, Hyoid bone, Cervical vertebrae.

Facts to Remember

- Eight bones in the calvaria and 14 facial bones make up the skull.
- Most of the joints are 'suture' type of joints. The joint between teeth and gums is gomphosis. There is a pair of temporomandibular joints, which is of synovial variety.
- The bony ossicles are malleus, incus and stapes and are 'bone within bone', as these are present in the petrous temporal bone. Between these three ossicles are two synovial joints.
- Diploe veins contain manufactured RBCs, granulocytes and platelets. These drain into the neighbouring veins.
- Paranasal sinuses give resonance to the voice, besides humidifying and warming up the inspired air.

BDC's Anatomy e-book

1. Principles governing fractures of the skull
2. Age changes in maxilla
3. Ossification of cranial bones
4. Development of neurocranium
5. Further reading
6. Viva voce



Chapter 2

Scalp, Temple and Face

Face is the most prominent part of the body. Facial muscles, being the muscles of facial expression, express a variety of emotions like happiness, joy, sadness, anger, frowning, grinning. The face, therefore, is an *index of mind*.

Competency:
AN27.1 Describe the layers of scalp, its blood supply, its nerve supply and surgical importance.

SCALP AND SUPERFICIAL TEMPORAL REGION

SCALP

The soft tissues covering the cranial vault form the scalp (Flowchart 2.1).

Extent of Scalp

The scalp extends as follows (Fig. 2.1):

Anteriorly — up to supraorbital margins.

Posteriorly — up to external occipital protuberance and superior nuchal lines.

On each side — up to the zygomatic arch and external acoustic meatus.

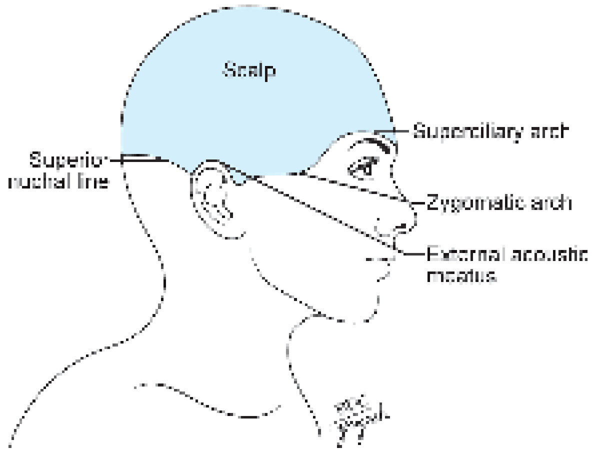

Scalp
Superciliary arch
Superior nuchal line
Zygomatic arch
External acoustic meatus

Fig. 2.1: Extent of the scalp (*Note*: Some authors consider that the scalp extends up to the superior temporal line)

Structure

Conventionally, the superficial temporal region is studied with the scalp, and the following description, therefore, will cover both regions.

The scalp is made up of five layers (*mnemonic*: **SCALP**) (Plate 2.1, Figs 2.2 to 2.4, Flowchart 2.2).

1. **S**kin
2. Superficial fascia (**C**onnective tissue)
3. Deep fascia in the form of the epicranial **a**poneurosis or galea aponeurotica with the occipitofrontalis muscle
4. **L**oose areolar tissue
5. **P**ericranium

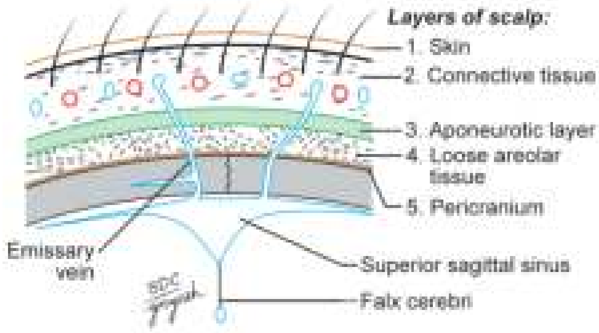

Layers of scalp:
1. Skin
2. Connective tissue
3. Aponeurotic layer
4. Loose areolar tissue
5. Pericranium
Emissary vein
Superior sagittal sinus
Falx cerebri

Fig. 2.2: Layers of the scalp

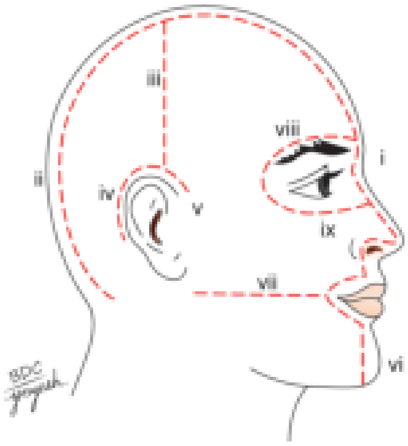
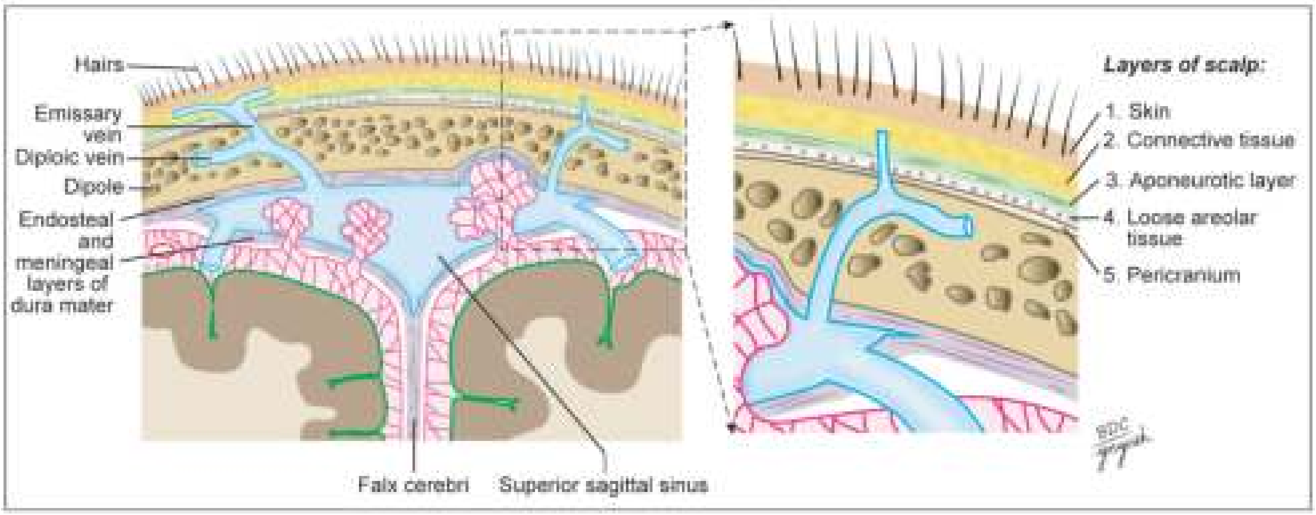
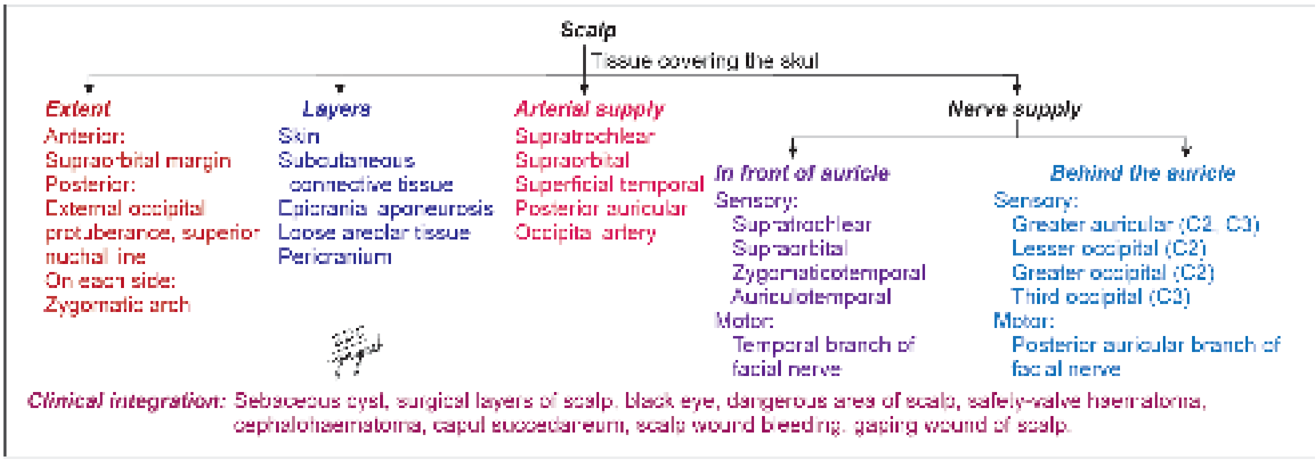

iii
viii
i
ii
iv
v
ix
vii
vi

Fig. 2.3: Lines of dissection for scalp, face and eyelids

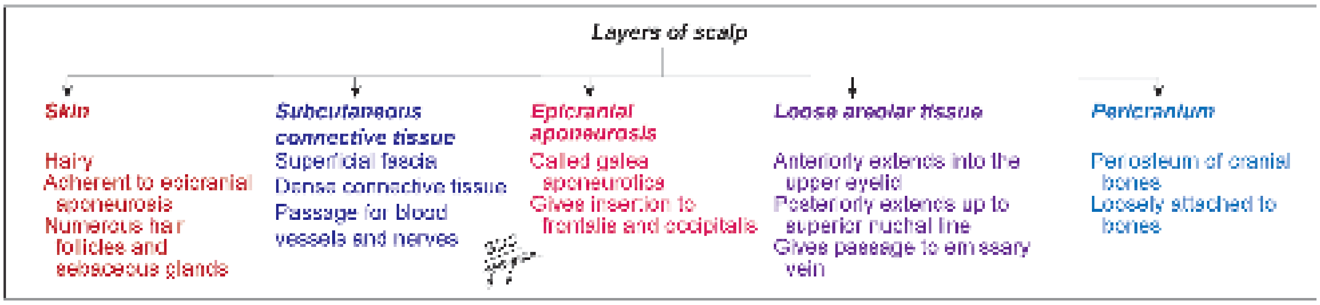
Plate 2.1: Layers of the scalp


Hairs
Emissary vein
Diploic vein
Diploe
Endosteal and meningeal layers of dura mater
Falx cerebri
Superior sagittal sinus
Layers of scalp:
1. Skin
2. Connective tissue
3. Aponeurotic layer
4. Loose areolar tissue
5. Pericranium

Flowchart 2.1: Scalp


Scalp
Tissue covering the skull
Extent
Anterior:
Supraorbital margin
Posterior:
External occipital protuberance, superior nuchal line
On each side:
Zygomatic arch
Layers
Skin
Subcutaneous connective tissue
Epicranial aponeurosis
Loose areolar tissue
Pericranium
Arterial supply
Supratrochlear
Supraorbital
Superficial temporal
Posterior auricular
Occipital artery
Nerve supply
In front of auricle
Sensory:
Supratrochlear
Supraorbital
Zygomaticotemporal
Auriculotemporal
Motor:
Temporal branch of facial nerve
Behind the auricle
Sensory:
Greater auricular (C2, C3)
Lesser occipital (C2)
Greater occipital (C2)
Third occipital (C3)
Motor:
Posterior auricular branch of facial nerve
Clinical integration: Sebaceous cyst, surgical layers of scalp, black eye, dangerous area of scalp, safety-valve haematoma, cephalohaematoma, caput succedaneum, scalp wound bleeding, gaping wound of scalp.

Flowchart 2.2: Layers of scalp


Layers of scalp
Skin
Hairy
Adherent to epicranial aponeurosis
Numerous hair follicles and sebaceous glands
Subcutaneous connective tissue
Superficial fascia
Dense connective tissue
Passage for blood vessels and nerves
Epicranial aponeurosis
Called galea aponeurotica
Gives insertion to frontalis and occipitalis
Loose areolar tissue
Anteriorly extends into the upper eyelid
Posteriorly extends up to superior nuchal line
Gives passage to emissary vein
Pericranium
Periosteum of cranial bones
Loosely attached to bones

1. **Skin** of scalp is hairy. It is adherent to the epicranial aponeurosis through the dense superficial fascia. It has more number of sweat glands and sebaceous glands.
2. The **connective tissue** (*superficial fascia*) is more fibrous and dense in the centre than at the periphery of the head. It contains many blood vessels. It binds the skin to the subjacent aponeurosis and provides the proper medium for the passage of vessels and nerves to the skin.
3. The ***occipitofrontalis muscle*** has two bellies, occipital or occipitalis and frontal or frontalis, both of which are inserted into the epicranial aponeurosis (Fig. 2.5). The *occipital bellies* are small and separate. Each arises from the lateral 2/3rd of the superior nuchal line and is supplied by the *posterior auricular* branch of the *facial nerve*.

The *frontal bellies* are longer, wider and partly united in the median plane. Each arises from the skin of the upper eyelid and forehead, mingling with the orbicularis oculi and the corrugator supercilia (Fig. 2.6). It is supplied by the *temporal branch* of the facial nerve.

The muscle raises the eyebrows and causes horizontal wrinkles in the skin of the forehead.

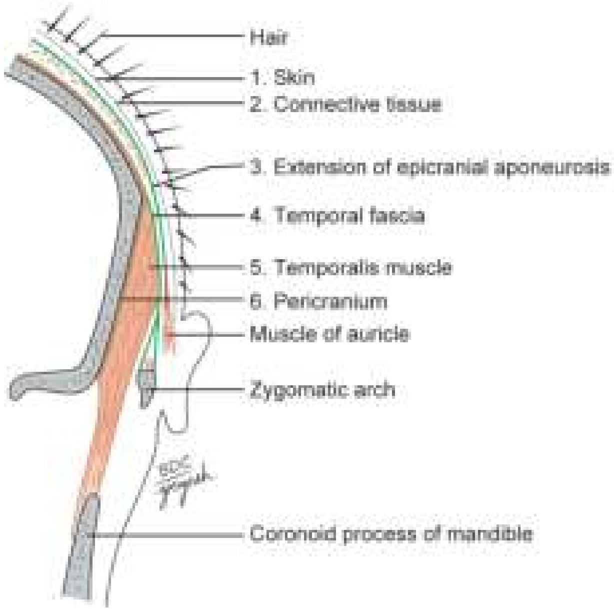

Hair
1. Skin
2. Connective tissue
3. Extension of epicranial aponeurosis
4. Temporal fascia
5. Temporalis muscle
6. Pericranium
Muscle of auricle
Zygomatic arch
Coronoid process of mandible

Fig. 2.4: Layers of superficial temporal region

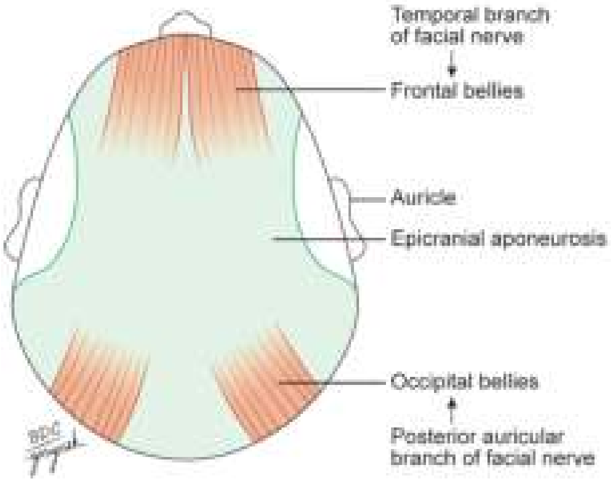

Temporal branch of facial nerve
Frontal bellies
Auricle
Epicranial aponeurosis
Occipital bellies
Posterior auricular branch of facial nerve

Fig. 2.5: Bellies of the occipitofrontalis muscle

4. The ***epicranial aponeurosis***, or ***galea aponeurotica*** is freely movable on the pericranium along with the overlying and adherent skin and fascia. Anteriorly, it receives the insertion of the frontalis; posteriorly, it receives the insertion of the occipitalis and is attached to the external occipital protuberance and the highest/superior nuchal lines in between the occipital bellies. On each side, the aponeurosis is attached to the superior temporal line but sends down a thin expansion that passes over the temporal fascia and is attached to the zygomatic arch.

   Note: The first three layers of scalp are called ***surgical layers of the scalp***. These are called 'scalp proper' also.

5. The layer of ***loose areolar tissue*** extends anteriorly into the eyelids because the frontalis muscle has no bony attachment; posteriorly to the highest and superior nuchal lines; and on each side to the superior temporal lines. It gives passage to the emissary veins which connect extracranial veins to intracranial venous sinuses.

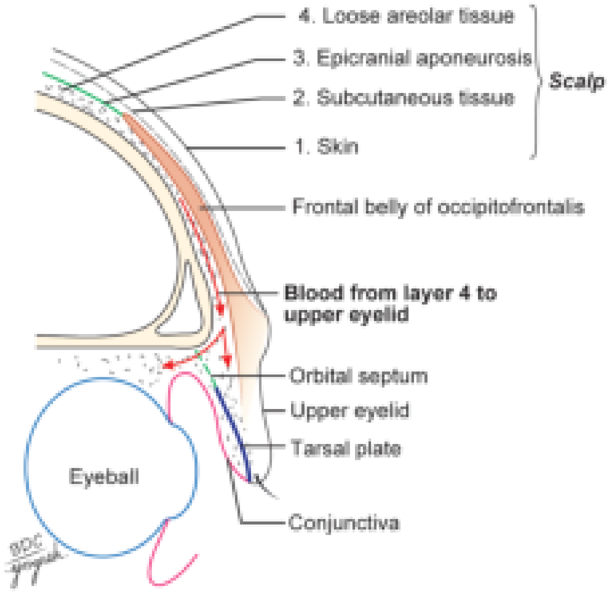

4. Loose areolar tissue
3. Epicranial aponeurosis
2. Subcutaneous tissue
1. Skin
Scalp
Frontal belly of occipitofrontalis
Blood from layer 4 to upper eyelid
Orbital septum
Upper eyelid
Tarsal plate
Eyeball
Conjunctiva

Fig. 2.6: Schematic section through the scalp and upper eyelid to show how fluids can pass from the subaponeurotic space or layer of loose areolar tissue of the scalp into the eyelid, and into the subconjunctival area. Note that this is possible because the frontalis muscle has no bony attachment

6. The ***pericranium*** is a periosteum of the skull bones. It is loosely attached to the surface of the bones but is firmly adherent to their sutures where the sutural ligaments bind the pericranium to the endocranium.

DISSECTION

Place 2–3 wooden blocks under the head to raise it about 10–12 cm from the table. Fig. 2.3 shows a median incision in the skin of scalp extending from root of the nose (i), to the prominent external occipital protuberance (ii). Give a coronal incision across the previous incision from root of one auricle to the other (iii). Extend the incision from the auricle to the mastoid process posteriorly (iv) and to root of zygomatic arch anteriorly (v). Reflect the skin in four flaps. Usually, the skin is so adherent to the subjacent connective tissue and aponeurotic layers that these all come off together. Dissect the layers, including the nerves, vessels, lymphatics and identify these structures in the cadaver.

SUPERFICIAL TEMPORAL REGION

It is the area between the superior temporal line and the zygomatic arch. This area contains the following six layers (Fig. 2.4):

1. Skin
2. Superficial fascia
3. Thin extension of epicranial aponeurosis which gives origin to extrinsic muscles of the auricle
4. Temporal fascia
5. Temporalis muscle
6. Pericranium.

Tempus means time. Greying of hair first starts here.

Arterial Supply of Scalp and Superficial Temporal Region

In front of the auricle (Fig. 2.7):

1. Supratrochlear
2. Supraorbital
3. Superficial temporal arteries

Behind the auricle:

1. Posterior auricular
2. Occipital (tortuous) arteries.

Note: The supratrochlear and supraorbital arteries are branches of the ophthalmic artery which in turn is a branch of the internal carotid artery. The superficial temporal is a smaller terminal branch of the external carotid artery.

The posterior auricular and occipital arteries are branches of the external carotid artery.

Thus, the scalp has a *rich blood supply* derived from both the internal and the external carotid arteries, the two systems anastomosing over the temple.

Venous Drainage

The veins of the scalp accompany the arteries and have similar names.

1. The ***supratrochlear*** and ***supraorbital veins*** unite at the medial angle of the eye forming the ***angular*** vein which continues down as the ***facial vein***.
2. The ***superficial temporal vein*** descends in front of the tragus, enters the parotid gland and joins the maxillary vein to form the ***retromandibular*** **vein**. This vein divides into two divisions.
   a. The ***anterior division*** of the retromandibular vein unites with the facial vein to form the *common facial vein* which drains into the internal jugular vein.
   b. The ***posterior division*** of the retromandibular vein unites with the *posterior auricular vein* to form the *external jugular vein* which ultimately drains into the *subclavian vein*. The occipital veins terminate in the suboccipital venous plexus.
3. ***Emissary veins*** connect the extracranial veins with the intracranial venous sinuses to equalise the pressure. These veins are valveless. The *parietal emissary vein* passes through the parietal foramen to enter the superior sagittal sinus. The *mastoid emissary vein* passes through the mastoid foramen to reach the sigmoid sinus.

   Extracranial infections may spread through these veins to intracranial venous sinuses.
4. ***Diploic veins*** start from the cancellous bone within the two tables of skull. These carry the newly formed blood cells into the general circulation. There are four veins on each side.
   a. The *frontal diploic vein* emerges at the supraorbital notch and open into the supraorbital vein.
   b. *Anterior temporal diploic vein* ends in anterior deep temporal vein or sphenoparietal sinus.
   c. *Posterior temporal diploic vein* ends in the transverse sinus.
   d. The *occipital diploic vein* opens either into the occipital vein or into the transverse sinus near the median plane.

Competency:

AN28.5 Describe cervical lymph nodes and lymphatic drainage of scalp, face and neck.

Lymphatic Drainage

The anterior part of the scalp drains into the preauricular or ***parotid lymph nodes***, situated on the surface of the parotid gland. The posterior part of the scalp drains into the posterior auricular or mastoid and occipital lymph nodes.

Nerve Supply

The scalp and temple are supplied by 10 nerves on each side. Out of these, five nerves (four sensory and one motor) enter the scalp in front of the auricle. The remaining five nerves (again four sensory and one motor) enter the scalp behind the auricle (Fig. 2.7 and Table 2.1).

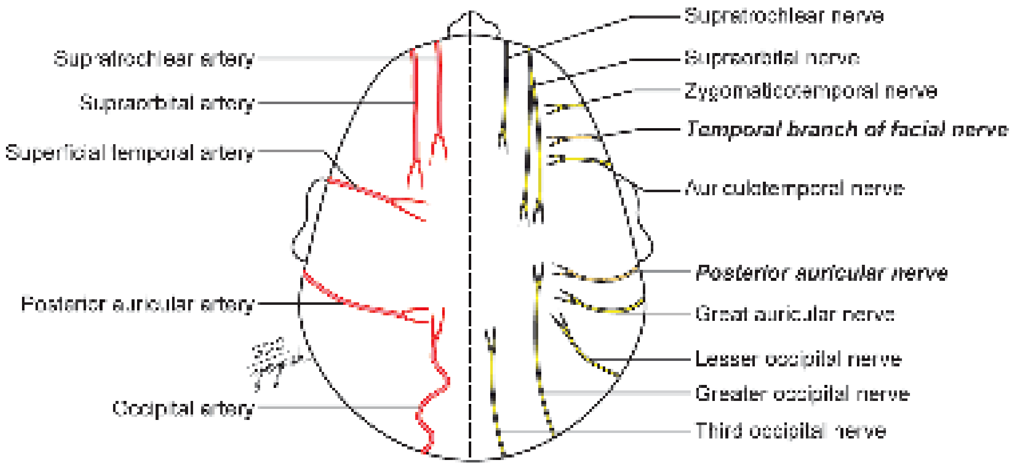

Supratrochlear artery
Supraorbital artery
Superficial temporal artery
Posterior auricular artery
Occipital artery
Supratrochlear nerve
Supraorbital nerve
Zygomaticotemporal nerve
Temporal branch of facial nerve
Auriculotemporal nerve
Posterior auricular nerve
Great auricular nerve
Lesser occipital nerve
Greater occipital nerve
Third occipital nerve

Fig. 2.7: Arterial and nerve supply of scalp and superficial temporal region

TABLE 2.1: Nerves of the scalp and superficial temporal region

In front of auricle	*Behind the auricle*
Sensory nerves Supratrochlear, branch of the frontal nerve (ophthalmic division of trigeminal nerve)	***Sensory nerves*** Posterior division of great auricular nerve (C2, C3) from cervical plexus
Supraorbital, branch of frontal nerve (ophthalmic division of trigeminal nerve)	Lesser occipital nerve (C2), from cervical plexus
Zygomaticotemporal, branch of zygomatic nerve (maxillary division of trigeminal nerve)	Greater occipital nerve (C2, dorsal ramus)
Auriculotemporal branch of mandibular division of trigeminal nerve	Third occipital nerve (C3, dorsal ramus)
Motor nerve Temporal branch of facial nerve	***Motor nerve*** Posterior auricular branch of facial nerve

CLINICAL ANATOMY

- Because of the abundance of sebaceous glands, the scalp is a common site for ***sebaceous cysts*** (Fig. 2.8).
- Collection of blood in the layer of loose connective tissue causes generalised swelling of the scalp. The blood may extend anteriorly into the root of the nose and into the eyelids (as frontalis muscle has no bony origin) resulting in ***black eye***. The posterior limit of such haemorrhage is not seen (Fig. 2.9). If bleeding is due to local injury, the posterior limit of haemorrhage is seen.
- ***Wounds*** of the scalp gape when the epicranial aponeurosis is divided transversely. Such wound needs stitching of layer of aponeurosis carefully (Fig. 2.10).
- Wounds of the scalp ***bleed profusely*** because the vessels are prevented from retracting by the fibrous fascia in second layer of scalp. Bleeding can be arrested by applying pressure at the site of injury by a tight cotton bandage against the bone.
- Because of the density of fascia, subcutaneous haemorrhages are never extensive and the inflammations in this layer cause little swelling but much pain.
- Because the pericranium is adherent to sutures, collections of fluid deep to the pericranium known as ***cephalhaematoma*** take the shape of the bone concerned when there is fracture of particular bone.
- ***Safety-valve haematoma***: Fractures of cranial vault cause escape of intracranial haematoma into sub-aponeurotic space of the scalp through fracture lines. Thus, it prevents compression of cerebrum. This process of collection of blood in sub-aponeurotic space (fourth layer) is called safety-valve hematoma.
- ***Dangerous area of scalp***: The layer of loose areolar tissue is a dangerous area of the scalp because emissary veins connect the veins of this layer with the dural venous sinuses. Hence, any infection of loose areolar tissue layer easily spreads to dural venous sinuses. It may lead to thrombosis of the dural venous sinuses which may be fatal.
- Because of the spread of blood, compression of brain is not seen and so this layer is also called ***safety layer***.
- Since the blood supply of scalp and superficial temporal region is very rich; avulsed portions need not be cut away. They can be replaced in position and stitched: They usually take up and heal well.
- ***Healing of avulsed scalp***: As the scalp and superficial temporal region is richly supplied by anastomosing vessels, the avulsed portion need not to be cut. It can be placed on position and stitched. It usually heals.
- ***Caput succedaneum***: It is a subcutaneous oedema of the scalp produced during delivery. It occurs due to interference in venous return during the passage of the head through the birth canal. It usually subsides in few days on its own.

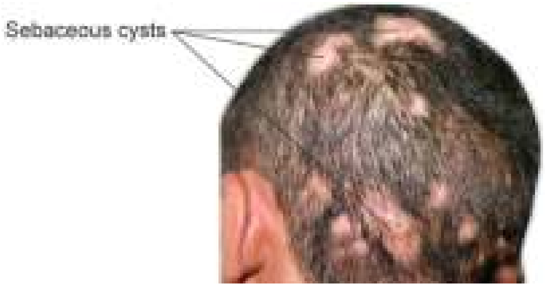


Fig. 2.8: Bilateral sebaceous cysts

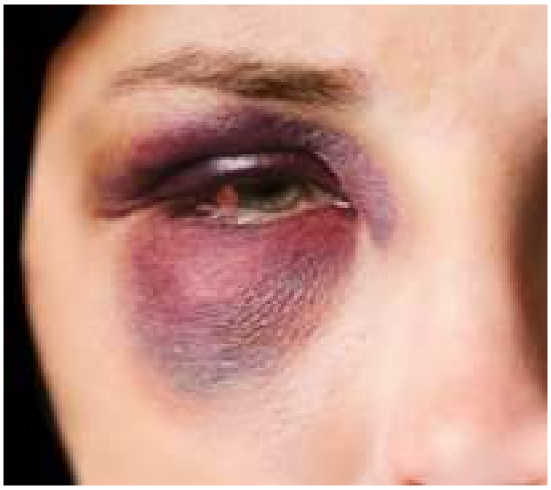


Fig. 2.9: Right eye—black eye due to injury to the scalp

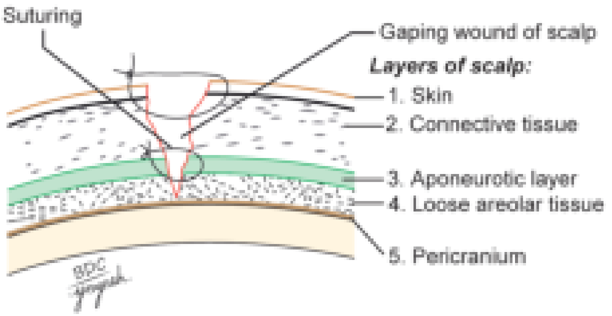


Fig. 2.10: Suturing of gaping wound of scalp

FACE

The face, or countenance, extends superiorly from the adolescent position of hairline, inferiorly to the chin and the base of the mandible and on each side to the auricle. The forehead is, therefore, common to both the face and the scalp.

SKIN OF THE FACE

1. The facial skin is *very vascular*. Rich vascularity makes the face blush and blanch. Wounds of the face bleed profusely but heal rapidly. The results of plastic surgery on the face are excellent for the same reason.
2. The facial skin is *rich in sebaceous and sweat glands*. Sebaceous glands keep the face oily but also cause *acne* in young adults. Sweat glands help in regulation of the body temperature.
3. *Laxity* of the greater part of the skin facilitates rapid spread of oedema. Renal oedema appears first in the eyelids and face before spreading to other parts of the body.
4. Boils in the nose and ear are acutely painful due to the *fixity* of the skin to the underlying cartilage.
5. Facial skin is very *elastic and thick* because the facial muscles are inserted into it. The wounds of the face, therefore, tend to gape.

SUPERFICIAL FASCIA

It contains:

1. Facial muscles, all of which are inserted into the skin
2. Vessels and nerves, to the muscles and to the skin
3. Variable amount of fat. Fat is absent from the eyelids but is well developed in the cheeks, forming the buccal pads that are very prominent in infants in whom they help in sucking.

Note: The *deep fascia is absent* from the face, except over the parotid gland where it forms the parotid fascia, and over the buccinator where it forms the *buccopharyngeal fascia*.

CLEAVAGE LINES OF SKIN IN THE FACE

The cleavage lines or ***Langer lines*** of skin tension are topological lines that are produced due to the parallel orientation of collagen fibres in the dermis and the underlying muscle [Karl Langer, Austrian anatomist, 1819–1887]. The orientation of the cleavage line in the skin of face is region-specific (Fig. 2.11).

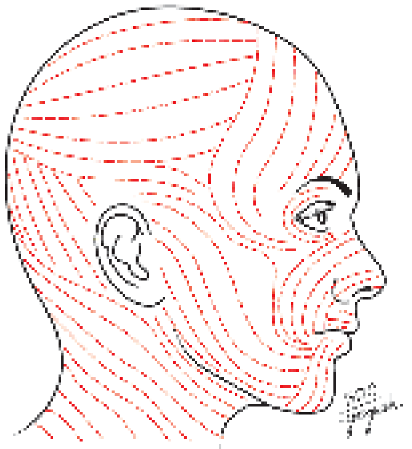


Fig. 2.11: The distribution of relaxed skin tension lines in the head and neck region

***Natural wrinkle lines*:** They result from repeated folding of skin perpendicular to the long axis of the underlying contracting muscle of facial expressions. Wrinkle lines become prominent in elderly due to loss of skin elasticity.

Note: To excise the lesions of the skin (scars, pigmented patches, or skin cancers), the incisions given along the natural wrinkle lines or cleavage lines produce less scarring.

DISSECTION

Give a median incision from the root of nose, across the dorsum of nose, centre of philtrum of upper lip, to centre of lower lip to the chin (vi). Give a horizontal incision from the angle of the mouth to posterior border of ramus of the mandible (vii). Reflect the lower flap towards and up to the lower border of mandible. Direct and reflect the upper flap till the auricle. Subjacent to the skin, the facial muscles are directly encountered as these are inserted in the skin. Identify the various functional groups of facial muscles. Trace the various motor branches of facial nerve emerging from the anterior border of parotid gland to supply these muscles. Amongst these motor branches on the face are the sensory branches of the three divisions of the trigeminal nerve. Try to identify all these with the help of their course given in the text.

Competencies:

AN28.1 Describe and demonstrate muscles of facial expression and their nerve supply.

AN28.6 Identify superficial muscles of face, their nerve supply and actions.

FACIAL MUSCLES

The facial muscles are subcutaneous muscles (Plates 2.2, and 2.3, Figs 2.12 to 2.14).

Peculiarities

1. Since these muscles are inserted into skin, they bring out various facial expressions. So, these are secondarily known as muscles of facial expression. These have small motor units.

Plate 2.2: Muscles of the facial expression (anterior view)

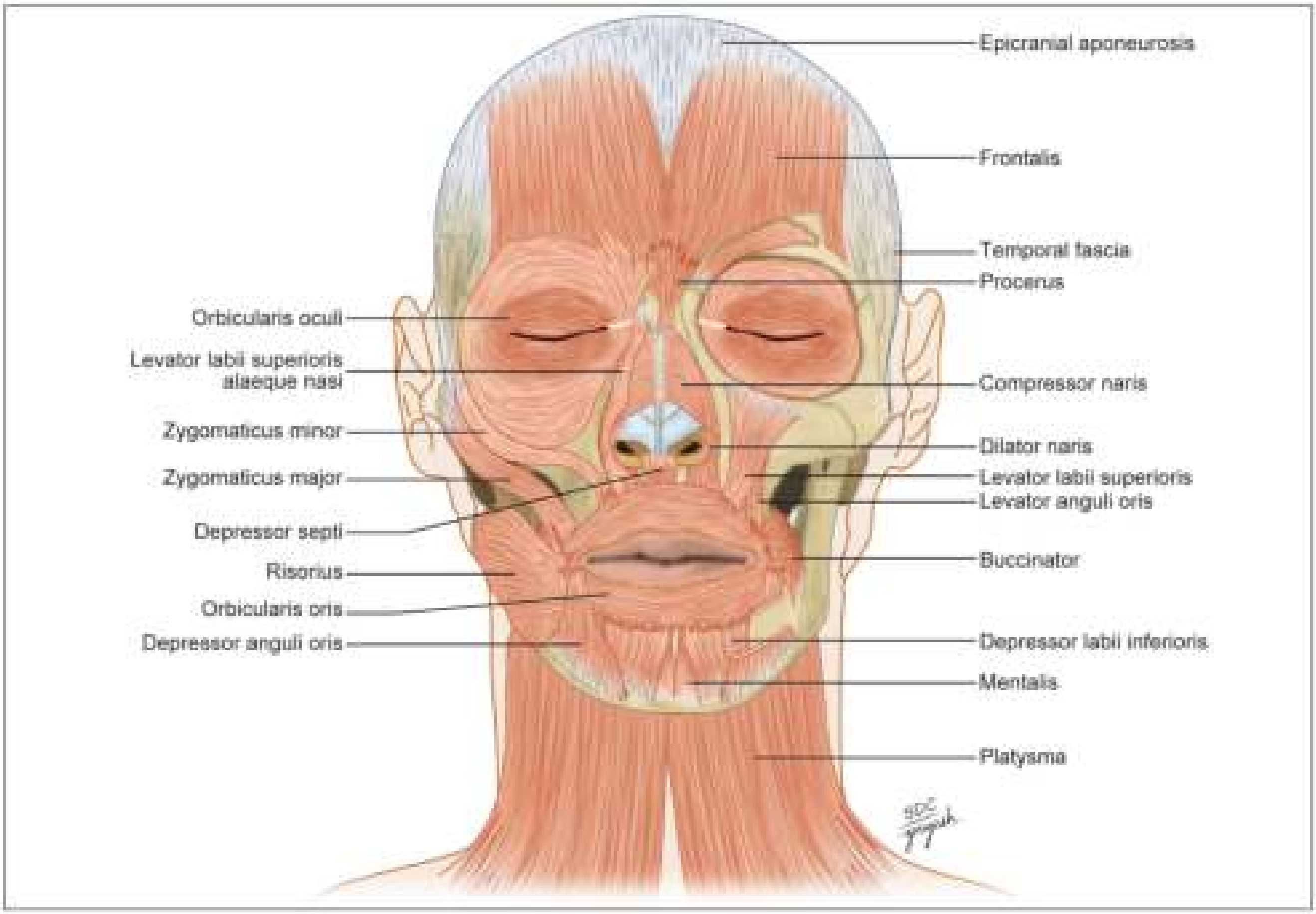
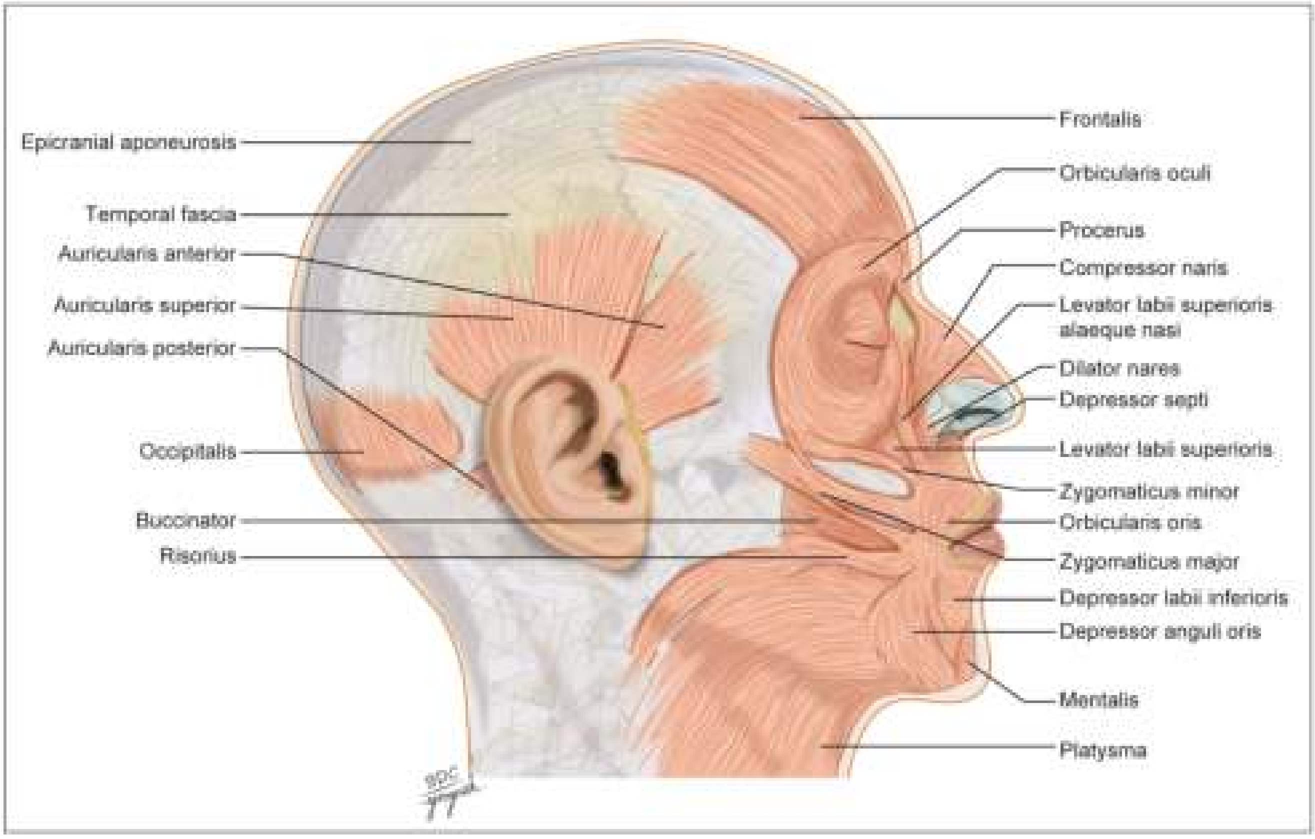

Epicranial aponeurosis
Frontalis
Temporal fascia
Procerus
Orbicularis oculi
Levator labii superioris alaeque nasi
Compressor naris
Zygomaticus minor
Dilator naris
Zygomaticus major
Levator labii superioris
Levator anguli oris
Depressor septi
Buccinator
Risorius
Orbicularis oris
Depressor anguli oris
Depressor labii inferioris
Mentalis
Platysma

Plate 2.3: Muscles of the facial expression (lateral view, note: levator anguli oris is not soon in this view as it lies in deeper plane)


Frontalis
Epicranial aponeurosis
Orbicularis oculi
Temporal fascia
Procerus
Auricularis anterior
Compressor naris
Auricularis superior
Levator labii superioris alaeque nasi
Auricularis posterior
Dilator nares
Depressor septi
Occipitalis
Levator labii superioris
Zygomaticus minor
Buccinator
Orbicularis oris
Risorius
Zygomaticus major
Depressor labii inferioris
Depressor anguli oris
Mentalis
Platysma

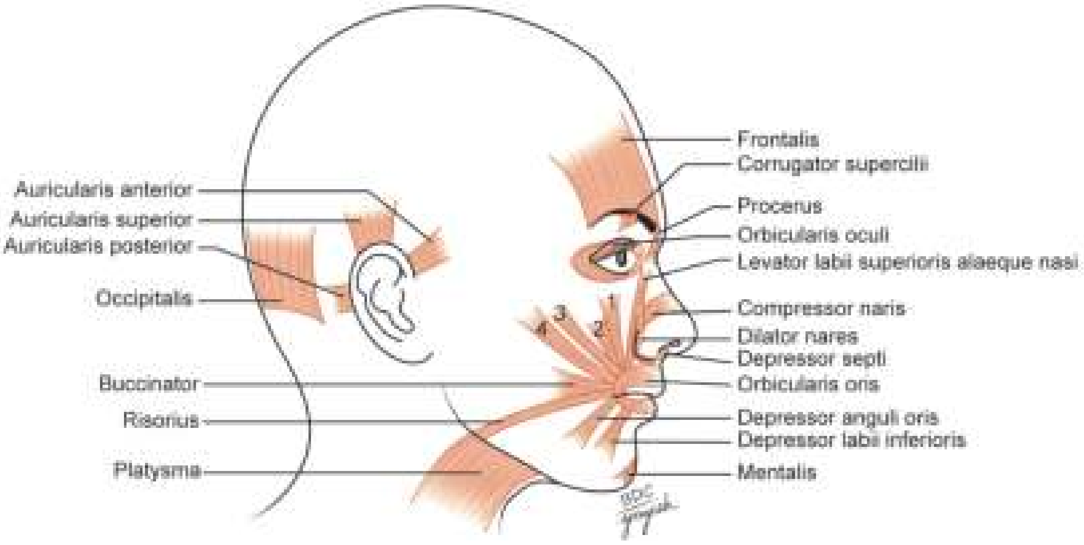

Auricularis anterior
Auricularis superior
Auricularis posterior
Occipitalis
Buccinator
Risorius
Platysma
Frontalis
Corrugator supercilii
Procerus
Orbicularis oculi
Levator labii superioris alaeque nasi
Compressor naris
Dilator nares
Depressor septi
Orbicularis oris
Depressor anguli oris
Depressor labii inferioris
Mentalis
1
2
3
4

Fig. 2.12: Muscles of facial expression (lateral view, 1: levator labii superioris, 2: levator anguli oris, 3: Zygomaticus minor, 4: Zygomaticus major)

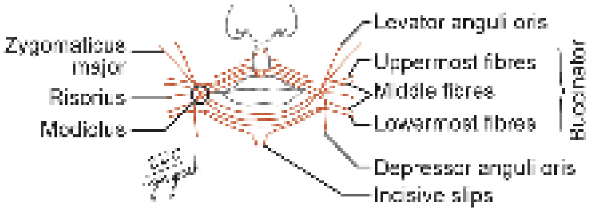

Zygomaticus major
Risorius
Modiolus
Levator anguli oris
Uppermost fibres
Middle fibres
Lowermost fibres
Buccinator
Depressor anguli oris
Incisive slips

Fig. 2.13: Orbicularis oris and buccinator muscles: Arrangement of fibres and formation of modiolus

2. *Embryologically*, they develop from the mesoderm of the 2nd branchial arch, and are, therefore, supplied by the facial nerve.
3. *Morphologically*, they represent the best remnants of the *panniculus carnosus*, a continuous subcutaneous muscle sheet seen in some animals. All of them are inserted into the skin.
4. *Topographically*, the muscles are grouped under the following six heads.
5. *Functionally*, most of these muscles may be regarded primarily as regulators of the three openings situated on the face, namely the palpebral fissures, the nostrils and the oral fissure. Each opening has a single sphincter and a variable number of dilators. Sphincters are naturally circular and the dilators radial in their arrangement. These muscles are better developed around the eyes and mouth than around the nose (Table 2.2).

Muscle of the Scalp

Occipitofrontalis—described in scalp.

Muscles of the Auricle

Situated around the ear:

1. Auricularis anterior
2. Auricularis superior
3. Auricularis posterior

These are vestigial muscles.

TABLE 2.2: Functional groups of facial muscles

Opening	*Sphincter*	*Dilators*
A. Palpebral fissure	Orbicularis oculi	1. Levator palpebrae superioris 2. Frontalis part of occipitofrontalis
B. Oral fissure	Orbicularis oris	All the muscles around the mouth, except the orbicularis oris, the sphincter and the mentalis, which does not mingle with orbicularis oris
C. Nostrils	Compressor naris	1. Dilator naris 2. Depressor septi 3. Medial slip of levator labii superioris alaeque nasi

Muscles of the Eyelids/Orbital Openings

1. Corrugator (Latin *to wrinkle*) supercilii (Fig. 2.12 and Table 2.3)
2. Orbicularis oculi (Fig. 2.12 and Table 2.3)
3. Levator palpebrae superioris (an extraocular muscle, supplied by sympathetic fibres and the third cranial nerve) is described in Chapter 13.

Muscles Around Nasal Opening

1. Procerus
2. Compressor naris
3. Dilator naris
4. Depressor septi

Muscles Around the Mouth

1. Orbicularis oris
2. Buccinator (Latin *cheek*)
3. Levator labii superioris alaeque nasi
4. Zygomaticus major
5. Levator labii superioris
6. Levator anguli oris
7. Zygomaticus minor

TABLE 2.3: The facial muscles (Figs 2.12 to 2.15)

Name	*Origin*	*Insertion*	*Actions*
Muscles of eyelid/orbital opening			
Corrugator supercilii	Medial end of superciliary arch	Skin of mid-eyebrow	Vertical lines on forehead, as in frowning
Orbicularis oculi			
a. Orbital part, on and around the orbital margin	Medial part of medial palpebral ligament, frontal process of maxilla and nasal part of frontal bone	Concentric rings return to the point of origin	Protects eye from bright light, wind and rain. Causes forceful closure of eyelids
b. Palpebral part, in the lids	Lateral part of medial palpebral ligament	Lateral palpebral raphe	Closes lids gently as in blinking and sleeping
c. Lacrimal part, lateral and deep to the lacrimal sac	Lacrimal fascia and posterior lacrimal crest, forms sheath for lacrimal sac	Pass laterally in front of tarsal plates of both eyelids	Dilates lacrimal sac for sucking of lacrimal fluid into the sac, directs lacrimal puncta into lacus lacrimalis; supports the lower lid
Muscles around nasal opening			
Procerus	Nasal bone and upper part of superior nasal cartilage	Skin of forehead between eyebrows and on bridge of the nose	Causes transverse wrinkles
Compressor naris	Maxilla just lateral to nose	Aponeurosis across dorsum of nose	Nasal aperture compressed
Dilator naris	Maxilla over the lateral incisor	Alar cartilage of nose	Nasal aperture dilated
Depressor septi	Maxilla over the medial incisor	Lower mobile part of nasal septum	Nose pulled inferiorly
Muscles around the mouth			
Orbicularis oris (comprises four quadrants: Upper, lower, right and left. Each quadrant consists of big pars peripheralis and small pars marginalis)	Pars peripheralis comprises of extrinsic fibres converging modiolus where these form triangular sheets going to each lip. Pars marginalis: These fibres arise from modiolus	The triangular sheets go to each lip, where these fibres interdigitate with opposite side fibres These fibres extend to vermilion zone where these interdigitate with fibres of opposite side	Closes lips and protrudes lips, numerous extrinsic muscles make it most versatile for various types of grimaces This part is associated with speech and helps in producing musical tones
Buccinator, the muscle of the cheek Pierced by: a. Parotid duct, and b. Buccal branch of mandibular nerve	1. Upper fibres, from maxilla opposite molar teeth 2. Lower fibres, from mandible, opposite molar teeth 3. Middle posterior fibres, from pterygomandibular raphe attached to pterygoid hamulus and inner aspect of mandible behind 3rd molar tooth	1. Upper fibres, straight to the upper lip 2. Lower fibres, straight to the lower lip 3. Middle fibres decussate upper fibres go to lower lip, while lower fibres reach the upper lip	Flattens cheek against gums and teeth; prevents accumulation of food in the vestibule. This is the *whistling muscle*
Levator labii superioris alaeque nasi	Frontal process of maxilla	Upper lip and alar	Lifts upper lip and dilates cartilage of nose the nostril
Zygomaticus major	Posterior aspect of lateral surface of zygomatic bone	Skin at the angle of the mouth	Pulls the angle upwards and laterally as in smiling and laughing
Levator labii superioris	Infraorbital margin of maxilla	Skin of upper lateral half of the upper lip	Elevates the upper lip, forms nasolabial groove
Levator anguli oris	Maxilla just below infraorbital foramen	Skin of angle of the mouth	Elevates angle of mouth, forms nasolabial groove
Zygomaticus minor	Anterior aspect of lateral surface of zygomatic bone	Upper lip medial to its angle	Elevates the upper lip
Depressor anguli oris	Oblique line of mandible below first molar, premolar and canine teeth	Skin at the angle of mouth and fuses with orbicularis oris	Draws angle of mouth downwards and laterally
Depressor labii inferioris	Anterior part of oblique line of mandible	Lower lip at midline, fuses with muscles from opposite side	Draws lower lip downward
Mentalis	Mandible inferior to incisor teeth	Skin of chin	Elevates and protrudes lower lip as it wrinkles skin on chin
Risorius	Fascia on the masseter muscle	Skin at the angle of the mouth	Retracts angle of mouth
Muscle of the neck			
Platysma	Upper parts of pectoral and deltoid fasciae Fibres run upwards and medially	Anterior fibres, to the base of the mandible; posterior fibres, to the skin of the lower face and lip and may be continuous with the risorius	Releases pressure of skin on the subjacent veins; depresses mandible; pulls the angle of the mouth downwards as in horror or fright

Modiolus: It is a compact, mobile fibromuscular structure present at about 1.25 cm lateral to the angle of the mouth opposite the upper second premolar tooth. The five muscles interlacing to form the modiolus are zygomaticus major, buccinator, levator anguli oris, risorius and depressor anguli oris.

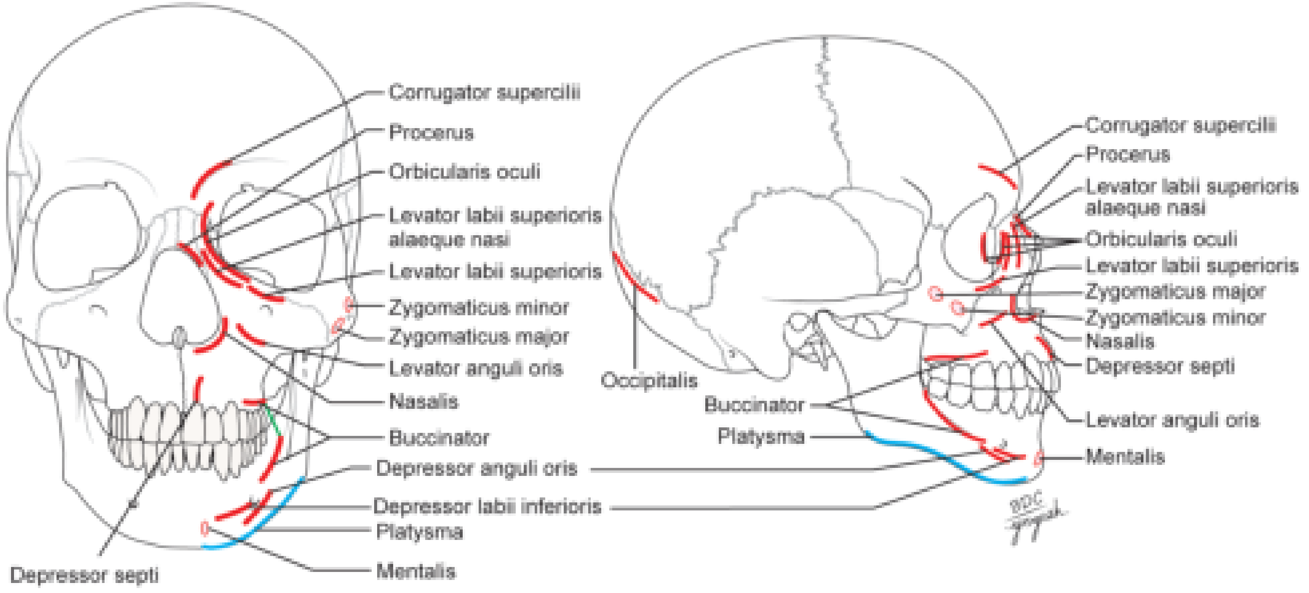

Corrugator supercilii
Procerus
Orbicularis oculi
Levator labii superioris alaeque nasi
Levator labii superioris
Zygomaticus minor
Zygomaticus major
Levator anguli oris
Nasalis
Buccinator
Depressor anguli oris
Depressor labii inferioris
Platysma
Mentalis
Depressor septi
Occipitalis
Corrugator supercilii
Procerus
Levator labii superioris alaeque nasi
Orbicularis oculi
Levator labii superioris
Zygomaticus major
Zygomaticus minor
Nasalis
Depressor septi
Buccinator
Platysma
Levator anguli oris
Mentalis

Fig. 2.14: Attachments of muscles of facial expression

8. Depressor anguli oris
9. Depressor labii inferioris
10. Mentalis (Latin *chin*)
11. Risorius (Latin *laughter*)

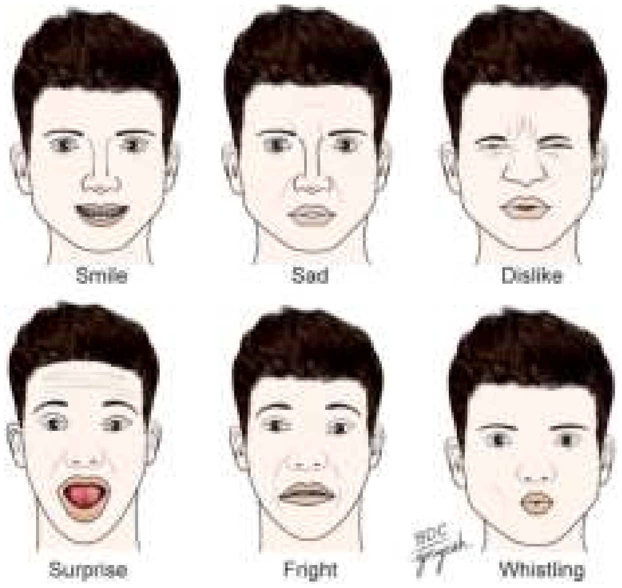

Smile
Sad
Dislike
Surprise
Fright
Whistling

Fig. 2.15: Some common facial expressions

Note: A few of the *common facial expressions* and the muscles producing them are given below (Fig. 2.15):

1. *Surprise:* Frontalis
2. *Dislike:* Corrugator supercilii and procerus
3. *Anger:* Dilator naris and depressor septi
4. *Smiling and laughing:* Zygomaticus major
5. *Grinning:* Risorius
6. *Sadness:* Levator labii superioris and levator anguli oris
7. *Grief:* Depressor anguli oris
8. *Closing the mouth:* Orbicularis oris
9. *Whistling/kissing:* Buccinator and orbicularis oris
10. *Doubt:* Mentalis
11. *Horror, terror and fright:* Platysma

Muscle of the Neck

Platysma (Greek *broad*).

Origin, insertion and actions of these muscles are given in Table 2.3.

Competency:
AN28.4 Describe and demonstrate branches of facial nerve with distribution.

NERVE SUPPLY OF FACE

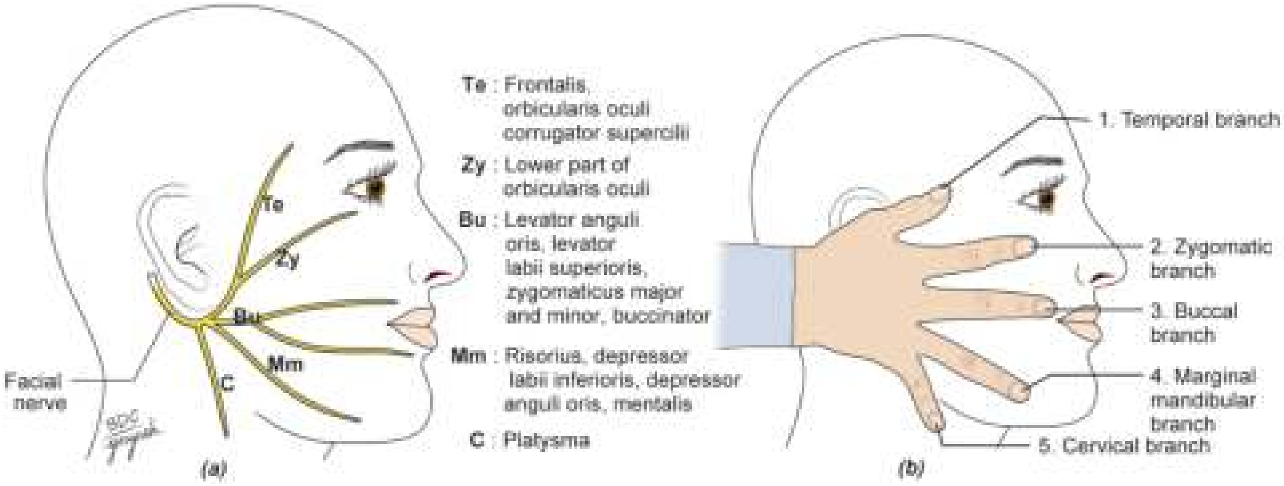
Motor Nerve Supply

The *facial nerve* is the motor nerve of the face. Its five terminal branches, temporal, zygomatic, buccal, marginal mandibular and cervical emerge from the parotid gland and diverge to supply the various facial muscles as follows:

1. Temporal — crosses zygomatic arch gives branches for frontalis, auricular muscles, orbicularis oculi.
2. Zygomatic — crosses zygomatic bone and gives branches for orbicularis oculi (lower eyelid part).
3. Buccal — supplies muscles of the cheek and upper lip.
4. Marginal mandibular — supplies muscles of lower lip.
5. Cervical — innervates platysma.

[*Mnemonic*: ***Five branches of the facial nerve (VII)*** (**T**en **Z**ebras **B**it **M**y **C**at): **T**emporal; **Z**ygomatic; **B**uccal; **M**arginal mandibular; **C**ervical]

Note: Branches of the facial nerve can be simulated by putting your right wrist on the right ear and spreading five digits: The thumb over the temporal region, the index finger on the zygomatic bone, middle finger on the upper lip, the ring finger on the lower lip and the little finger over the neck (Figs 2.16a and b).


Te : Frontalis, orbicularis oculi corrugator supercilii
Zy : Lower part of orbicularis oculi
Bu : Levator anguli oris, levator labii superioris, zygomaticus major and minor, buccinator
Mm : Risorius, depressor labii inferioris, depressor anguli oris, mentalis
C : Platysma
Te
Zy
Bu
Mm
C
Facial nerve
(a)
1. Temporal branch
2. Zygomatic branch
3. Buccal branch
4. Marginal mandibular branch
5. Cervical branch
(b)

Figs 2.16a and b: Terminal branches of the facial nerve and their distribution

Competency:
AN28.7 Explain the anatomical basis of facial nerve palsy.

CLINICAL ANATOMY

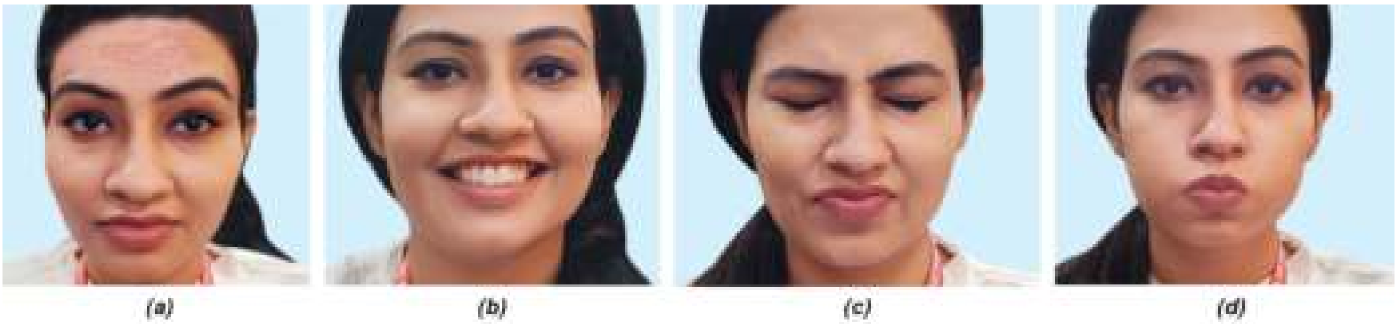
- ***Clinical testing of muscle of facial expressions:*** The facial nerve is examined by testing the following facial muscles (Figs 2.17a to d).
  a. *Frontalis:* Ask the patient to look upwards without moving his head, and look for the normal horizontal wrinkles on the forehead.
  b. *Dilators of mouth:* Showing the teeth.
  c. *Orbicularis oculi:* Tight closure of the eyes.
  d. *Buccinator:* Puffing the mouth and then blowing forcibly as in whistling.
- ***Bell's palsy***: Infranuclear lesion (Fig. 2.18) of the facial nerve, at the stylomastoid foramen is known as *Bell's palsy*, upper and lower quarters of the muscles of face on the same side get paralysed with atrophy of the facial muscles. It also causes loss of taste in most of anterior 2/3rd of the tongue.
  - The face becomes asymmetrical and is drawn up to the normal side.
  - The affected side is motionless. Wrinkles disappear from the forehead.
  - The eye cannot be closed leading to keratitis.
  - Any attempt to smile draws the mouth to the normal side.
  - During mastication, food accumulates between the teeth and the cheek.
  - Articulation of labials is impaired. Tears flow out from the eye.

  Saliva flows down from the angle of mouth.
- ***Supranuclear facial nerve palsy***: In supranuclear lesions of the facial nerve; usually a part of hemiplegia, with injury of corticonuclear fibres, only the lower quarter of the opposite side of face is paralysed. The upper quarter with the frontalis and orbicularis oculi escapes due to its bilateral representation in the cerebral cortex (Fig. 2.19). Only voluntary movements are affected and emotional expressions remain normal as there are separate pathways for voluntary and emotional movements. There is no atrophy of facial muscles.

Competency:
AN28.2 Describe sensory innervation of face.

Sensory Nerve Supply of Face

The ***trigeminal nerve*** through its three branches is the chief sensory nerve of the face (Figs 2.20 and 2.21, Flowchart 2.3 and Table 2.4). The skin over the angle of the jaw and over the parotid gland is supplied by the great auricular nerve (C2, C3).



Figs 2.17a to d: (a) Test for frontalis, (b) test for dilators of mouth, (c) test for orbicularis oculi, and (d) test for buccinator

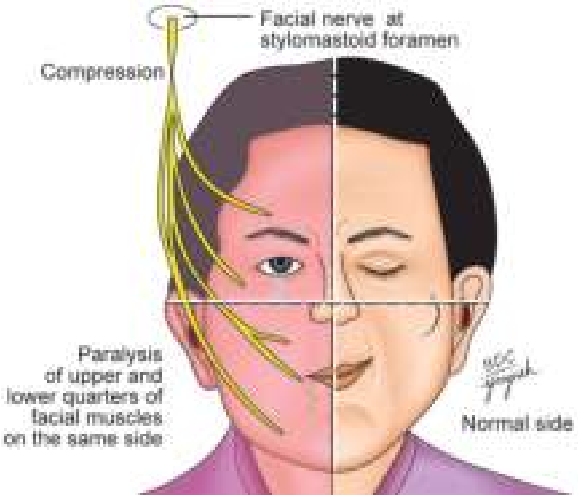

Facial nerve at stylomastoid foramen
Compression
Paralysis of upper and lower quarters of facial muscles on the same side
Normal side

Fig. 2.18: Infranuclear lesion of right facial nerve or Bell's palsy

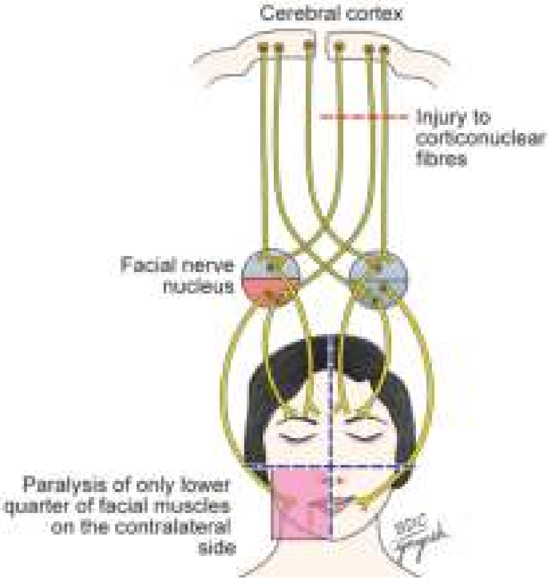
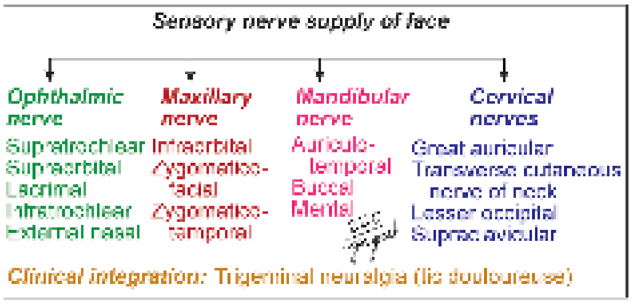

Cerebral cortex
Injury to corticonuclear fibres
Facial nerve nucleus
Paralysis of only lower quarter of facial muscles on the contralateral side

Fig. 2.19: Supranuclear lesion of left facial nerve

Flowchart 2.3: Sensory nerve supply of face


Sensory nerve supply of face
Ophthalmic nerve
Maxillary nerve
Mandibular nerve
Cervical nerves
Supratrochlear
Supraorbital
Lacrimal
Infratrochlear
External nasal
Infraorbital
Zygomatico-facial
Zygomatico-temporal
Auriculo-temporal
Buccal
Mental
Great auricular
Transverse cutaneous nerve of neck
Lesser occipital
Supraclavicular
Clinical integration: Trigeminal neuralgia (tic douloureuse)

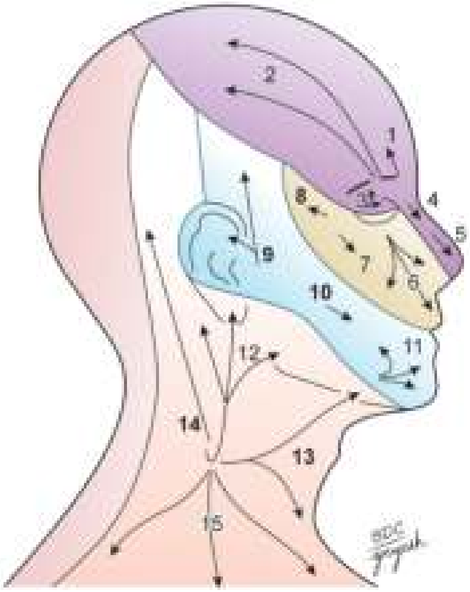

1
2
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Fig. 2.20: The sensory nerves of the face and neck: (1) Supratrochlear, (2) supraorbital, (3) palpebral branch of lacrimal, (4) infratrochlear, (5) external nasal, (6) infraorbital, (7) zygomaticofacial, (8) zygomaticotemporal, (9) auriculotemporal, (10) buccal, (11) mental, (12) great auricular, (13) transverse cutaneous nerve of neck, (14) lesser occipital and (15) supraclavicular

TABLE 2.4: Cutaneous nerves of the face

Source	*Cutaneous nerve*	*Area of distribution*
a. Ophthalmic division of trigeminal nerve	1. Supratrochlear nerve	Upper eyelid and forehead
	2. Supraorbital nerve	Upper eyelid, frontal air sinus, scalp
	3. Lacrimal nerve	Lateral part of upper eyelid
	4. Infratrochlear nerve	Medial parts of both eyelids
	5. External nasal nerve	Lower part of dorsum and tip of nose
b. Maxillary division of trigeminal nerve	6. Infraorbital nerve	Lower eyelid, side of nose and upper lip
	7. Zygomaticofacial nerve	Upper part of cheek
	8. Zygomaticotemporal nerve	Anterior part of temporal region
c. Mandibular division of trigeminal nerve	9. Auriculotemporal nerve	Upper two-thirds of lateral side of auricle, temporal region
	10. Buccal nerve	Skin of lower part of cheek
	11. Mental nerve	Skin over chin
d. Cervical plexus	12. Anterior division of great auricular nerve (C2, C3)	Skin over angle of the jaw and over the parotid gland
	13. Upper and lower divisions of transverse (anterior) cutaneous nerve of neck (C2, C3)	Lower margin of the lower jaw and upper part of neck
	14. Lesser occipital	Back of auricle
	15. Supraclavicular	Front of thorax till 2nd costal cartilage and skin over upper ½ of deltoid muscle

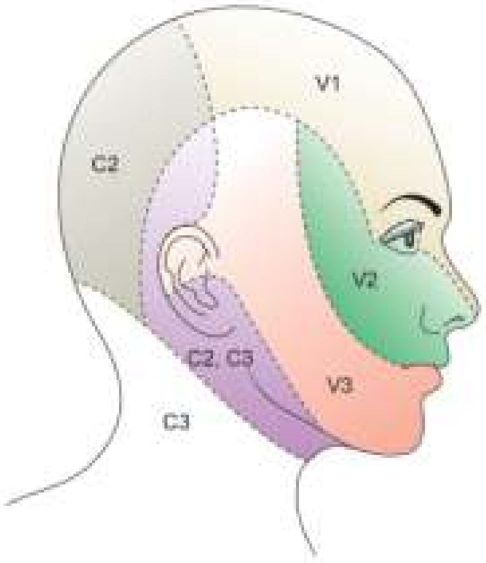

V1
C2
V2
C2, C3
V3
C3

Fig. 2.21: Sensory innervation of the face (V1: Ophthalmic division of trigeminal nerve, V2: Maxillary division of trigeminal nerve, V3: Mandibular division of trigeminal nerve)

In addition to most of the skin of the face, the sensory distribution of the trigeminal nerve is also to the nasal cavity, the paranasal air sinuses, the eyeball, the mouth cavity, palate, cheeks, gums, teeth and anterior 2/3rd of tongue and the supratentorial part of the dura mater, including that lining the anterior and middle cranial fossae (Fig. 2.16).

CLINICAL ANATOMY

- The sensory distribution of the trigeminal nerve explains why ***headache*** is a uniformly common symptom in involvements of the nose (common cold, boils), the paranasal air sinuses (sinusitis), infections and inflammations of teeth and gums, refractive errors of the eyes and infection of the meninges as in meningitis.
- ***Trigeminal neuralgia*** (***tic douloureux***) may involve one or more of the three divisions of the trigeminal nerve. It causes attacks of very severe burning and scalding pain along the distribution of the affected nerve. Pain is relieved either: (a) By injecting 90% alcohol into the affected division of the trigeminal ganglion, or (b) by sectioning the affected nerve, the main sensory root, or the spinal tract of the trigeminal nerve which is situated superficially in the medulla. The procedure is called medullary tractotomy.

ARTERIES OF THE FACE

Features

The face is richly vascular. It is supplied by:

1. The facial artery,
2. The transverse facial artery and
3. Arteries that accompany the cutaneous nerves, which are small branches of ophthalmic, maxillary and superficial temporal arteries (Fig. 2.22, Flowchart 2.4).

Competency:
AN28.3 Describe and demonstrate origin/formation, course, branches/tributaries of facial vessels.

Facial Artery (Facial Part)

The facial artery is the ***chief artery of the face*** (Fig. 2.22, Flowchart 2.4). It is a branch of the external carotid artery given off in the carotid triangle just above the level of the tip of the greater cornua of the hyoid bone. In its cervical course, it passes through the submandibular region and finally enters the face.

Course

1. It enters the face by winding around the base of the mandible, and by piercing the deep cervical fascia, at the anteroinferior angle of the masseter muscle. It can be palpated here and is called '**anaesthetist's artery**'.
2. First, it runs upwards and forwards to a point 1.25 cm lateral to the angle of the mouth. Then, it ascends as angular artery by the side of the nose up to the medial angle of the eye, where ***angular artery*** terminates by supplying the lacrimal sac; and by anastomosing with the dorsal nasal branch of the ophthalmic artery.

   The course of the artery in the neck is described in submandibular region.

Note: The facial artery is very ***tortuous***. The tortuosity of the artery prevents its walls from being unduly stretched during movements of the mandible, the lips and the cheeks. It lies between the superficial and deep muscles of the face.

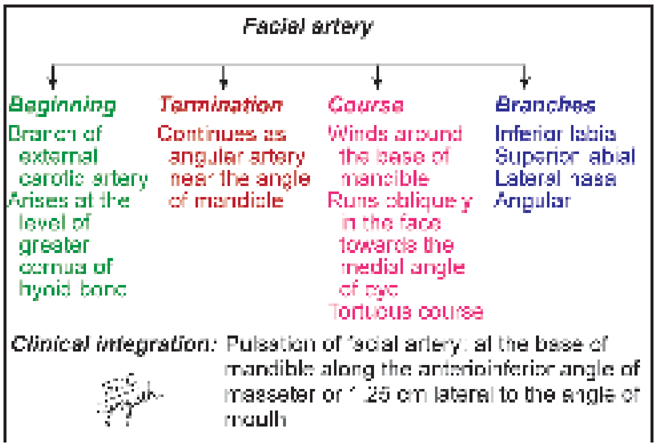
Branches

The anterior branches on the face are large and named. They are:

1. ***Inferior labial***, to the lower lip.
2. ***Superior labial***, to the upper lip and the anteroinferior part of the nasal septum.
3. ***Lateral nasal***, to the ala and dorsum of the nose.

The posterior branches are *small* and unnamed.

Flowchart 2.4: Facial artery


Facial artery
Beginning
Branch of external carotid artery
Arises at the level of greater cornua of hyoid bone
Termination
Continues as angular artery near the angle of mandible
Course
Winds around the base of mandible
Runs obliquely in the face towards the medial angle of eye
Tortuous course
Branches
Inferior labial
Superior labial
Lateral nasal
Angular
Clinical integration: Pulsation of facial artery at the base of mandible along the anteroinferior angle of masseter or 1.25 cm lateral to the angle of mouth

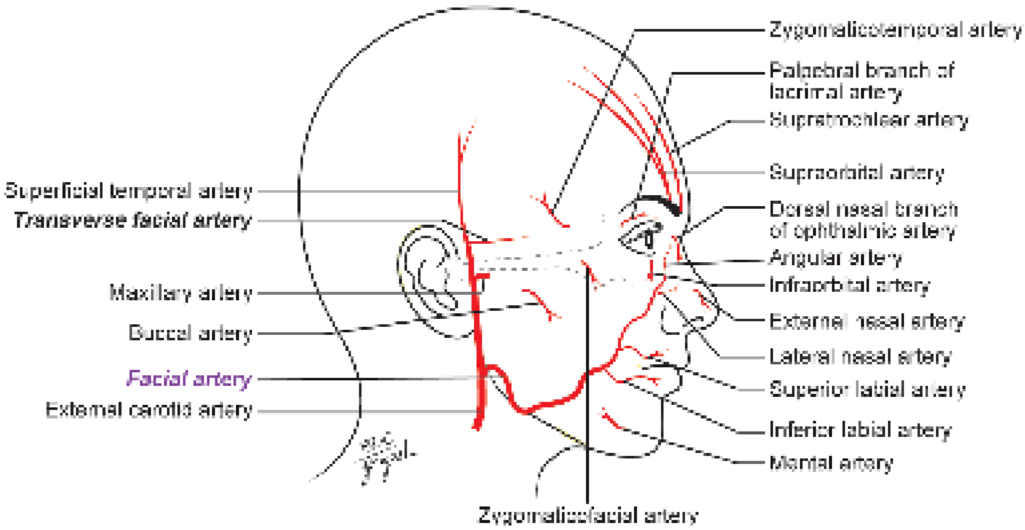

Zygomaticotemporal artery
Palpebral branch of lacrimal artery
Supratrochlear artery
Supraorbital artery
Dorsal nasal branch of ophthalmic artery
Angular artery
Infraorbital artery
External nasal artery
Lateral nasal artery
Superior labial artery
Inferior labial artery
Mental artery
Zygomaticofacial artery
Superficial temporal artery
Transverse facial artery
Maxillary artery
Buccal artery
Facial artery
External carotid artery

Fig. 2.22: Arteries of the face

Anastomoses

1. The large anterior branches anastomose with similar branches of the opposite side and with the mental artery. In the lips, anastomoses are large, so that cut arteries spurt from both ends.
2. Small posterior branches anastomose with the transverse facial and infraorbital arteries.
3. At the medial angle of the eye, terminal branches of the facial artery anastomose with branches of the ophthalmic artery. This is, therefore, a site for anastomoses between the branches of the external and internal carotid arteries.

CLINICAL ANATOMY

- Pulsation of facial artery: It can be felt at two sites:
  1. At the base of mandible along the anteroinferior angle of masseter.
  2. At about 1.25 cm lateral to the angle of mouth.
- Rich vascularity of the face helps in rapid healing of wounds.

Transverse Facial Artery

This small artery is a branch of the *superficial temporal artery* (Fig. 2.22). After emerging from the parotid gland, it runs forwards over the masseter between the parotid duct and the zygomatic arch, accompanied by the upper buccal branch of the facial nerve. It supplies the parotid gland and its duct, masseter and the overlying skin and ends by anastomosing with neighbouring arteries.

DISSECTION

Tortuous facial artery enters the face at the lower border of mandible. Dissect its course from the anteroinferior angle of masseter muscle running to the angle of mouth till the medial angle of eye, reflecting off some of the facial muscles, if necessary.

Straight facial vein runs on a posterior plane than the artery.

Identify buccopharyngeal fascia on the external surface of buccinator muscle. Clean the deeply placed buccinator muscle situated lateral to the angle of mouth.

Identify parotid duct, running across the cheek 2 cm below the zygomatic arch. The duct pierces buccal pad of fat, buccopharyngeal fascia, buccinator muscle, mucous membrane of the mouth to open into its vestibule opposite second upper molar tooth.

Competency:
AN28.8 Explain surgical importance of deep facial vein.

VEINS OF THE FACE

1. The veins of the face accompany the arteries and drain into:
   a. Common facial vein
   b. Retromandibular vein.

   These veins communicate with the cavernous sinus.
2. The veins on each side form a '***W-shaped' arrangement***'. Each corner of the 'W' is prolonged upwards into the scalp and downwards into the neck (Fig. 2.23).
3. The ***facial vein*** is the largest vein of the face with no valves. It begins as the angular vein at the medial angle of the eye. It is formed by the union of the supratrochlear and supraorbital veins. The angular vein continues as the facial vein, running downwards and backwards behind the facial artery, but with a straighter course. It crosses the anteroinferior angle of the masseter, pierces the deep fascia, crosses the submandibular gland and joins the anterior division of the retromandibular vein below the angle of the mandible to form the common facial vein. The latter drains into the internal jugular vein. It is represented by a line drawn just behind the facial artery. The other veins drain into neighbouring veins.

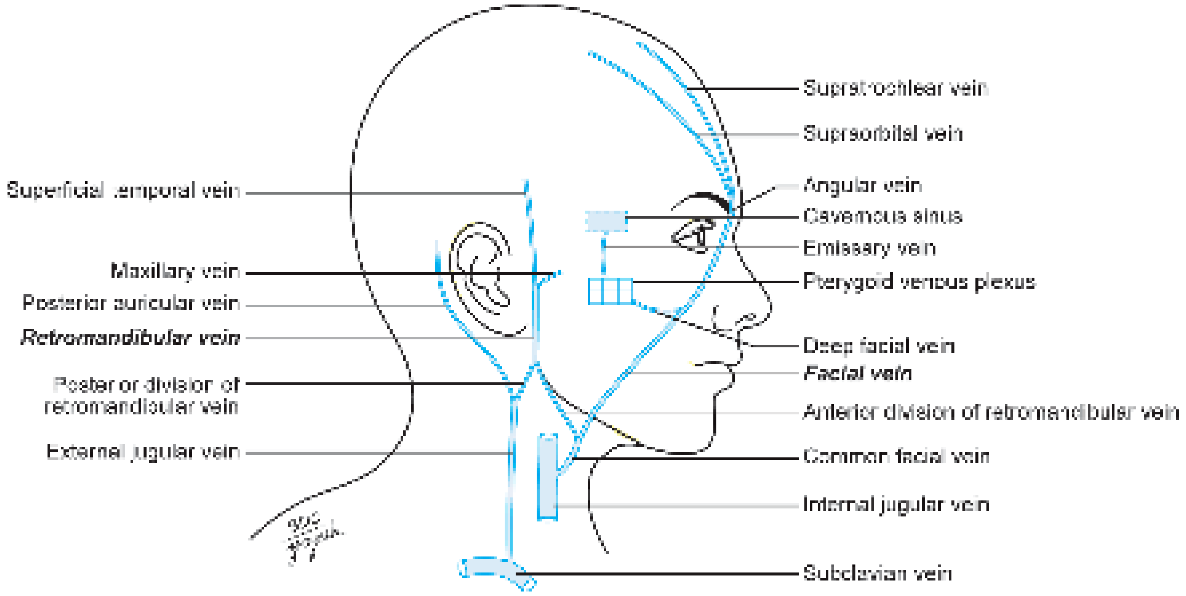

Supratrochlear vein
Supraorbital vein
Superficial temporal vein
Angular vein
Cavernous sinus
Emissary vein
Maxillary vein
Pterygoid venous plexus
Posterior auricular vein
Retromandibular vein
Deep facial vein
Facial vein
Posterior division of retromandibular vein
Anterior division of retromandibular vein
External jugular vein
Common facial vein
Internal jugular vein
Subclavian vein

Fig. 2.23: The veins of the scalp, face and their deep connections with the cavernous sinus and the pterygoid plexus of veins

4. *Deep connections* of the facial vein include:
   a. A communication between the supraorbital and superior ophthalmic veins.
   b. Another connection with the pterygoid plexus through the ***deep facial* vein** which passes backwards over the buccinator. The connection between facial vein and cavernous sinus is shown in Fig. 2.23.

CLINICAL ANATOMY

Dangerous area of face:

- The dangerous area of face is the lower part of nose, upper lip and adjoining parts of cheek (Fig. 2.24)
- ***Anatomical basis:***
  The venous blood from this area is drained by facial vein. This facial vein has two peculiarities that make this area as dangerous area of face:
  1. Facial vein is devoid of valves.
  2. Facial vein communicates with the cavernous sinus through
     i. Angular vein and supraorbital vein that communicate with superior ophthalmic vein (which is tributary of cavernous sinus).
     ii. Deep facial vein that communicates with pterygoid veinous plexus (which has communication with cavernous sinus via emissary veins).
  3. Facial vein rests on the facial muscles which facilitates the spread of infection and emboli from facial vein to the cavernous sinus.

  Thus, the infection from the dangerous area of the face may spread intracranially to the cavernous sinus.

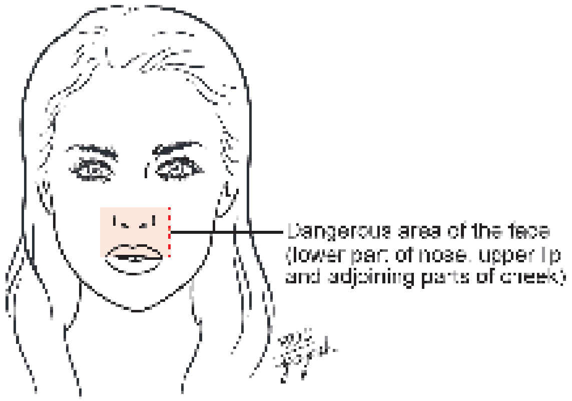

Dangerous area of the face (lower part of nose, upper lip and adjoining parts of cheek)

Fig. 2.24: Dangerous area of the face (stippled). Spread of infection from this area can cause thrombosis of the cavernous sinus

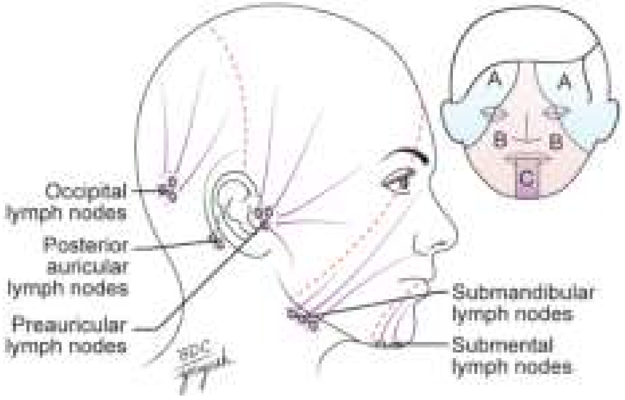

A
A
B
B
C
Occipital lymph nodes
Posterior auricular lymph nodes
Preauricular lymph nodes
Submandibular lymph nodes
Submental lymph nodes

Fig. 2.25: The lymph nodes and lymphatic territories of the face. Area A drains into the preauricular nodes, area B drains into the submandibular nodes and area C drains into the submental nodes

LYMPHATIC DRAINAGE OF THE FACE

The face has three lymphatic territories (Fig. 2.25):

1. ***Upper territory***, including the greater part of the forehead, lateral halves of eyelids, conjunctiva, lateral part of the cheek and parotid area, drains into the *preauricular parotid nodes*.
2. ***Middle territory***, including a strip over the median part of the forehead, external nose, upper lip, lateral

part of the lower lip, medial halves of the eyelids, medial part of the cheek and the greater part of lower jaw, drains into the *submandibular nodes*.

3. ***Lower territory***, including the central part of the lower lip and the chin, drains into the *submental nodes*.

Labial, Buccal and Molar Mucous Glands

The labial and buccal mucous glands are numerous. They lie in the submucosa of the lips and cheeks. The molar mucous glands, four or five, lie on the buccopharyngeal fascia around the parotid duct. All these glands open into the vestibule of the mouth.

EYELIDS OR PALPEBRAE

1. The space between the two eyelids is the ***palpebral fissure*** (Fig. 2.26). The two lids are fused to form the medial and lateral angles or ***canthi*** of the eye.
2. At the inner canthus, there is a small triangular space, the ***lacus lacrimalis***. Within it, there is an elevated ***lacrimal caruncle***, made up of modified skin and skin glands.
3. Lateral to the caruncle, the bulbar conjunctiva is pinched up to form a vertical fold called the ***plica semilunaris***.
4. Each eyelid is attached to the margins of the orbital opening. Its free edge is broad and has a rounded outer lip and a sharp inner lip. The outer lip presents two or more rows of eyelashes or cilia, except in the boundary of the lacus lacrimalis.
5. At the point where eyelashes cease, there is a ***lacrimal papilla*** on the summit of which there is the ***lacrimal punctum***. Near the inner lip of the free edge, there is a row of openings of the tarsal glands.
6. The free margin of both eyelids is subdivided into: Lateral 5/6th, the ciliary part with eyelashes and medial 1/6th, the lacrimal part, which lacks cilia.

Structure

Each lid is made up of the following layers from without inwards (Fig. 2.27):

1. Skin
2. Superficial fascia
3. Orbicularis oculi (palpebral part)
4. Tarsal plate and palpebral fascia
5. Palpebral conjunctiva.

Note:

1. ***Skin*** is thin, loose and easily distensible by oedema fluid or blood.
2. ***Superficial fascia*** is without any fat. It contains the palpebral part of the orbicularis oculi. Deep to the muscle is loose areolar tissue which is continuous with loose areolar tissue of the scalp.
3. ***Palpebral fascia*** of the two lids forms the ***orbital septum***. Its thickenings form ***tarsal plates*** or *tarsi* in the lids and the ***palpebral ligaments*** at the angles (Plate 2.4, Fig. 2.28).

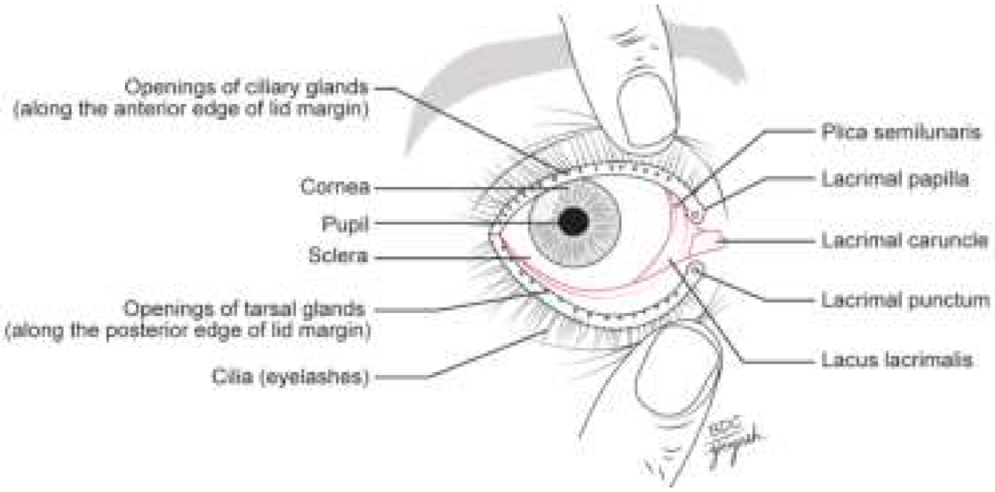

Openings of ciliary glands (along the anterior edge of lid margin)
Cornea
Pupil
Sclera
Openings of tarsal glands (along the posterior edge of lid margin)
Cilia (eyelashes)
Plica semilunaris
Lacrimal papilla
Lacrimal caruncle
Lacrimal punctum
Lacus lacrimalis

Fig. 2.26: Features of the palpebral fissure

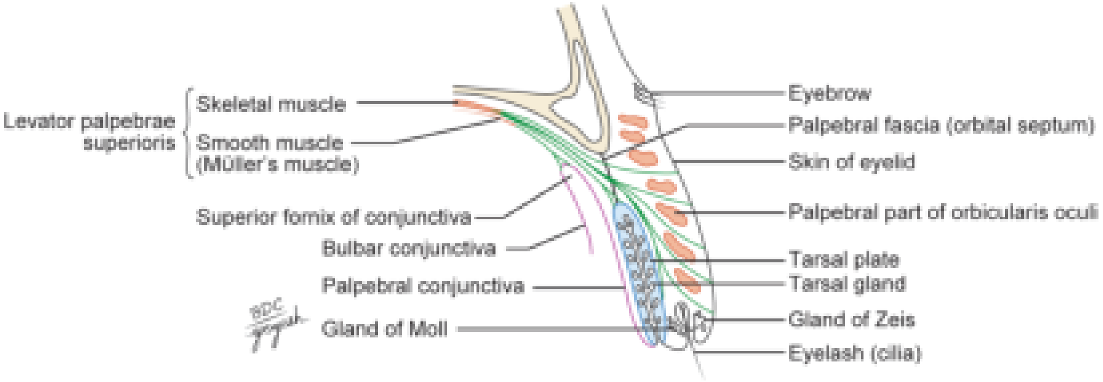
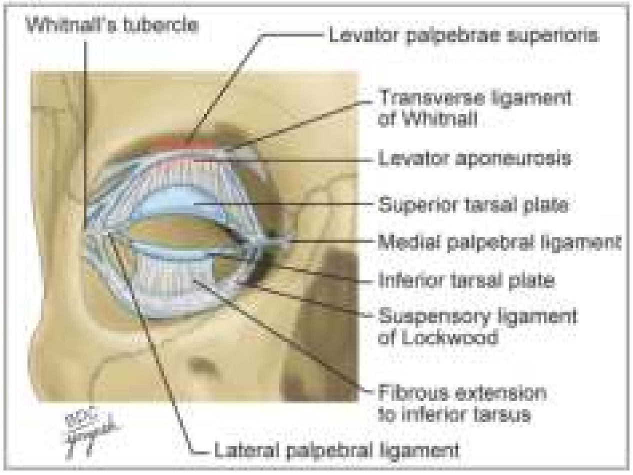

Levator palpebrae superioris
Skeletal muscle
Smooth muscle (Müller's muscle)
Superior fornix of conjunctiva
Bulbar conjunctiva
Palpebral conjunctiva
Gland of Moll
Eyebrow
Palpebral fascia (orbital septum)
Skin of eyelid
Palpebral part of orbicularis oculi
Tarsal plate
Tarsal gland
Gland of Zeis
Eyelash (cilia)

Fig. 2.27: Structure of the eyelid (sagittal section of upper eyelid)

Plate 2.4: Tarsal plates and palpebral fascia


Whitnall's tubercle
Levator palpebrae superioris
Transverse ligament of Whitnall
Levator aponeurosis
Superior tarsal plate
Medial palpebral ligament
Inferior tarsal plate
Suspensory ligament of Lockwood
Fibrous extension to inferior tarsus
Lateral palpebral ligament

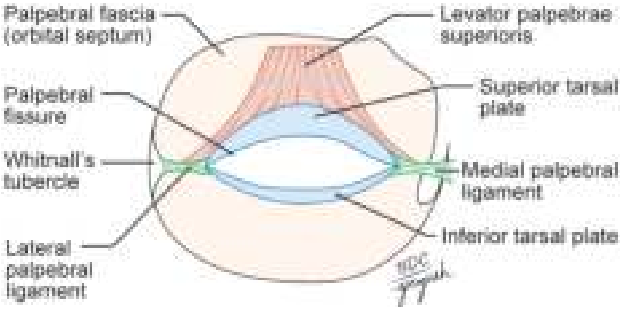

Palpebral fascia (orbital septum)
Palpebral fissure
Whitnall's tubercle
Lateral palpebral ligament
Levator palpebrae superioris
Superior tarsal plate
Medial palpebral ligament
Inferior tarsal plate

Fig. 2.28: Tarsal plates and palpebral fascia

Tarsi are thin plates of condensed fibrous tissue located near the lid margins. They give stiffness to the lids.

The palpebral fascia (orbital septum) is pierced by:

a. Palpebral part of lacrimal gland
b. Fibres of levator palpebral superioris
c. Vessels and nerves entering the face from the orbit.

4. The upper tarsus receives two tendinous slips from the ***levator palpebrae superioris***, one from voluntary part and another from involuntary part or ***Müller's muscle***.
5. ***Tarsal glands*** or ***meibomian glands*** are embedded in the posterior surface of the tarsi; their ducts open in a row behind the cilia.
6. The ***conjunctiva*** lines the posterior surface of the tarsus.
7. Apart from the usual glands of the skin and mucous glands in the conjunctiva, the larger glands found in the lids are:
   a. Large sebaceous glands also called ***Zeis glands*** at the lid margin associated with cilia.
   b. Modified sweat glands or ***Moll's glands*** at the lid margin closely associated with Zeis glands and cilia.
   c. Sebaceous or *tarsal glands* are also known as *meibomian glands*.

Blood Supply

The eyelids are supplied by:

1. The superior and inferior palpebral branches of the ophthalmic artery.
2. The lateral palpebral branch of the lacrimal artery.

They form an arcade in each lid.

The veins drain into the ophthalmic and facial veins.

Nerve Supply

The upper eyelid is supplied by the lacrimal, supraorbital, supratrochlear and infratrochlear nerves from lateral to medial side.

The lower eyelid is supplied by the infraorbital and infratrochlear nerves.

Lymphatic Drainage

The medial halves of the lids drain into the submandibular nodes, and the lateral halves into the preauricular nodes.

CLINICAL ANATOMY (Plate 2.5)

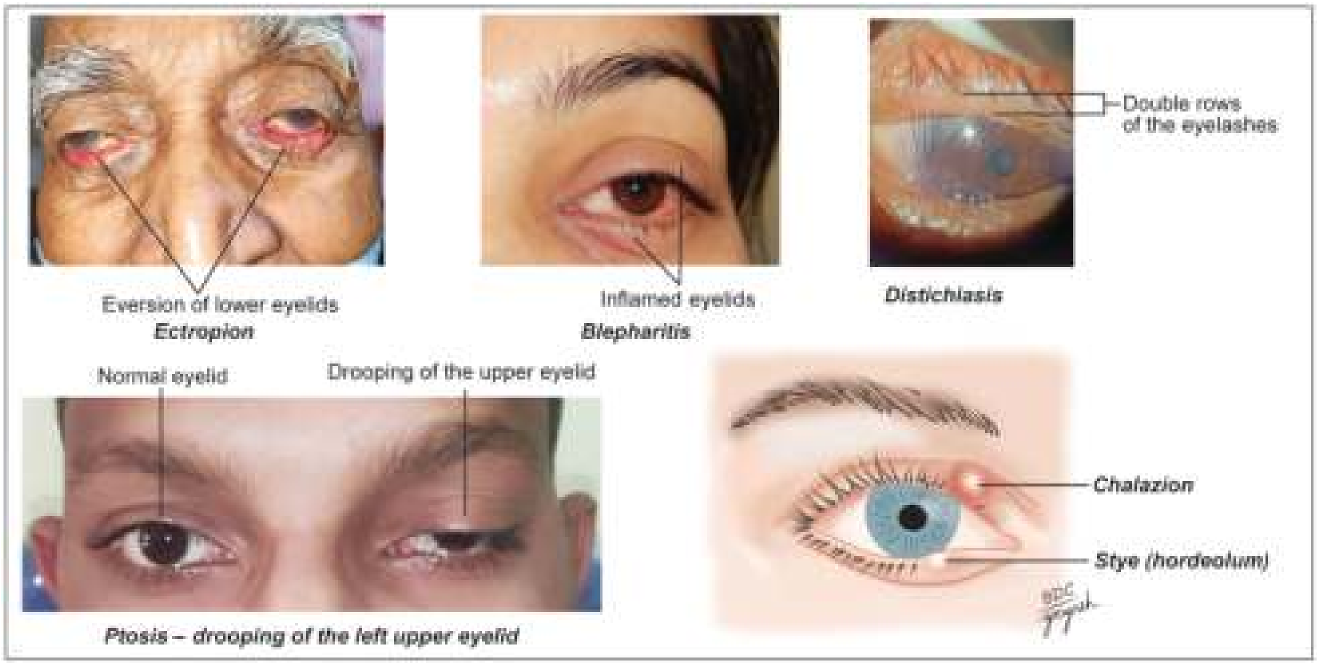
- The ***Müller's muscle*** or involuntary part of levator palpebrae superioris is supplied by sympathetic fibres from the superior cervical ganglion. Paralysis of this muscle leads to partial ***ptosis***. This is part of the ***Horner's syndrome***.
- ***Conjunctivitis*** is one of the commonest diseases of the eye. It may be caused by infection or by allergy. The palpebral conjunctiva is examined for anaemia and for conjunctivitis; the bulbar conjunctiva for jaundice.
- Foreign bodies are often lodged in a groove situated 2 mm from the edge of each eyelid.
- ***Chalazion*** is inflammation of a tarsal gland, causing a localised swelling pointing inwards.
- ***Ectropion*** is due to eversion of the lower lacrimal punctum. It usually occurs in old age due to laxity of skin.
- ***Trachoma*** is a contagious granular conjunctivitis caused by the trachoma virus. It is regarded as the commonest cause of blindness.
- ***Stye*** or ***hordeolum*** is a suppurative inflammation of one of the glands of Zeis. The gland is swollen, hard and painful and the whole of the lid is oedematous. The pus points near the base of one of the cilia.
- ***Blepharitis*** is inflammation of the eyelids, especially of the lid margin.

DISSECTION

Give a circular incision around the roots of eyelids (Fig. 2.3 – viii and ix). This will separate the orbital part of orbicularis oculi from the palpebral parts. Carefully reflect the palpebral part towards the palpebral fissure. Identify the structures present beneath the muscle as given in the text.

The upper and lower eyelids are movable curtains that protect the eyes from foreign bodies and bright light. They keep the cornea clean and moist. The upper eyelid is larger and more movable than the lower eyelid.

Plate 2.5: Some diseases of eyelids


Eversion of lower eyelids
Ectropion
Inflamed eyelids
Blepharitis
Double rows of the eyelashes
Distichiasis
Normal eyelid
Drooping of the upper eyelid
Ptosis – drooping of the left upper eyelid
Chalazion
Stye (hordeolum)

(*Image courtesy*: Dr Rohit Rao)

Competency:
AN31.4 Enumerate components of lacrimal apparatus.

LACRIMAL APPARATUS

COMPONENTS

The structures concerned with secretion and drainage of the lacrimal or tear fluid constitute the lacrimal apparatus. It is made up of the following parts (Figs 2.29 and 2.30, Flowchart 2.5):

1. Lacrimal gland and its ducts
2. Conjunctival sac
3. Lacrimal puncta
4. Lacrimal canaliculi
5. Lacrimal sac
6. Nasolacrimal duct.

Lacrimal Gland

It is a ***serous gland*** situated chiefly in the lacrimal fossa on the anterolateral part of the roof of the bony orbit and partly on the upper eyelid. Small *accessory lacrimal glands* are found in the conjunctival fornices. These are also called ***Krause's gland***.

The gland is 'J' shaped, being indented by the tendon of the *levator palpebrae superioris* muscle. It has:

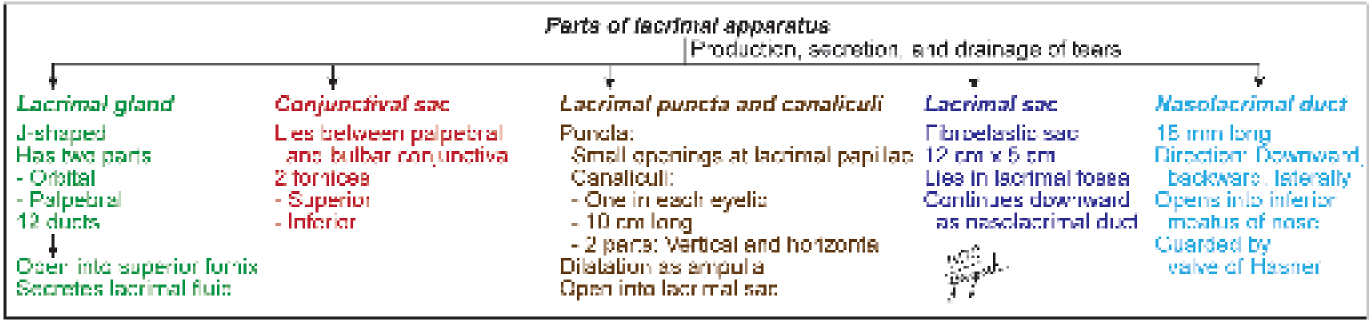
a. An *orbital part* that is larger and deeper and
b. A *palpebral part* smaller and superficial, lying within the eyelid (Fig. 2.29).

Ducts of lacrimal gland: About 12 *ducts* pierce the conjunctiva of the upper lid and open into the conjunctival sac near the superior fornix. Most of the ducts of the orbital part pass through the palpebral part.

Note: Removal of the palpebral part of the lacrimal gland is functionally equivalent to removal of the entire gland. After removal, the conjunctiva and cornea are moistened by accessory lacrimal glands, if present.

Nerve supply: The gland is supplied by the lacrimal branch of the ophthalmic artery and by the *lacrimal nerve*. The nerve has both sensory and secretomotor fibres. Flowchart 2.6 shows the secretomotor fibres for lacrimal gland (Fig. 2.31, Flowchart 2.6).

Flowchart 2.5: Parts of lacrimal apparatus


Parts of lacrimal apparatus
Production, secretion, and drainage of tears
Lacrimal gland
J-shaped
Has two parts
- Orbital
- Palpebral
12 ducts
Open into superior fornix
Secretes lacrimal fluid
Conjunctival sac
Lies between palpebral and bulbar conjunctiva
2 fornices
- Superior
- Inferior
Lacrimal puncta and canaliculi
Puncta:
Small openings at lacrimal papillae
Canaliculi:
- One in each eyelid
- 10 cm long
- 2 parts: Vertical and horizontal
Dilatation as ampulla
Open into lacrimal sac
Lacrimal sac
Fibroelastic sac
12 cm x 5 cm
Lies in lacrimal fossa
Continues downward as nasolacrimal duct
Nasolacrimal duct
15 mm long
Direction: Downward, backward, laterally
Opens into inferior meatus of nose
Guarded by valve of Hasner

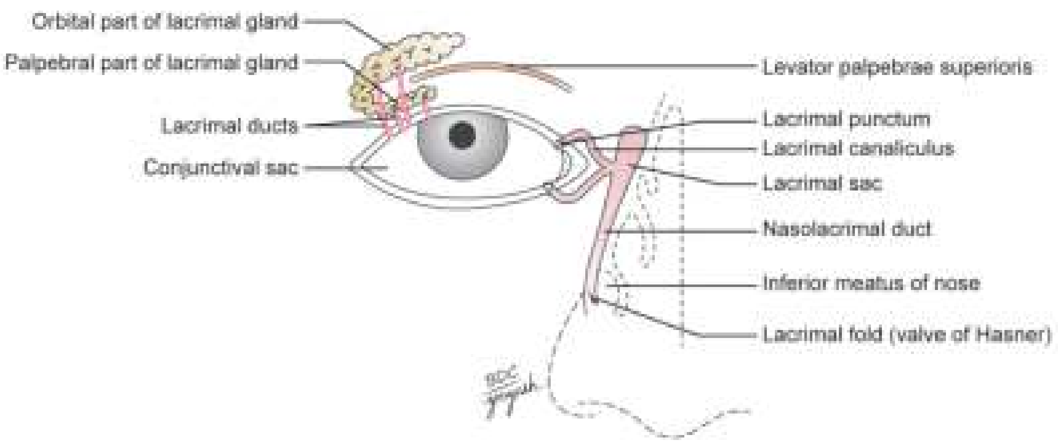

Orbital part of lacrimal gland
Palpebral part of lacrimal gland
Lacrimal ducts
Conjunctival sac
Levator palpebrae superioris
Lacrimal punctum
Lacrimal canaliculus
Lacrimal sac
Nasolacrimal duct
Inferior meatus of nose
Lacrimal fold (valve of Hasner)

Fig. 2.29: Components of lacrimal apparatus

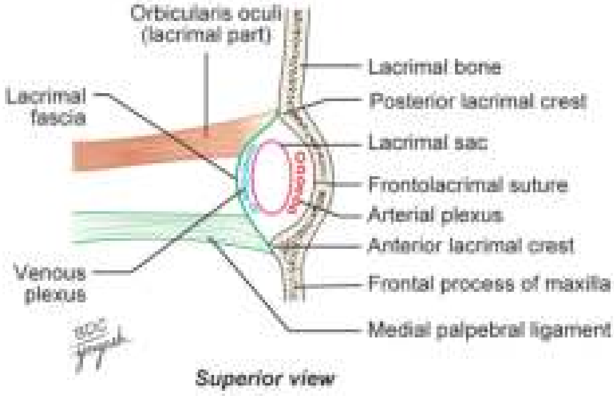

Orbicularis oculi (lacrimal part)
Lacrimal fascia
Venous plexus
Lacrimal bone
Posterior lacrimal crest
Lacrimal sac
Frontolacrimal suture
Arterial plexus
Anterior lacrimal crest
Frontal process of maxilla
Medial palpebral ligament
Superior view

Fig. 2.30: Relations of the lacrimal sac (horizontal section passing through the medial part of the orbit)

Functions: Lacrimal glands secrete about 1 ml of lacrimal fluid per day. Most of it evaporates, and rest is drained into the lacrimal sac.

Function of lacrimal fluid

1. Keep the cornea moist which is essential for its transparency.
2. Nourishes the cornea.
3. Flushes the conjunctival sac.
4. Prevents infection by the action of its lysozymes.
5. Medium for expression with shedding of tears during grief, sorrow and extreme emotional happiness.

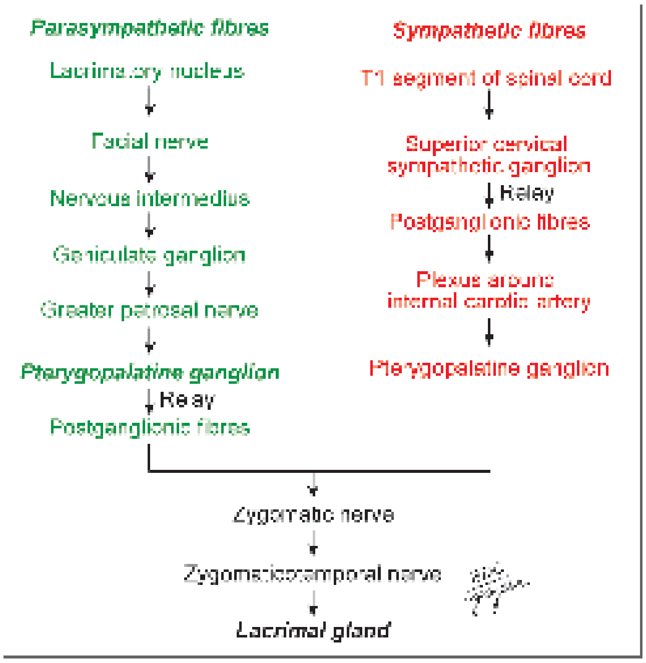
Conjunctival Sac

The conjunctiva lining the deep surfaces of the eyelids is called ***palpebral conjunctiva*** and that lining the front of the eyeball is called ***bulbar conjunctiva*** (Figs 2.29 and 2.30). The potential space between the palpebral and bulbar parts is the ***conjunctival sac***.

The lines along which the palpebral conjunctiva of the upper and lower eyelids is reflected onto the eyeball are called the superior and inferior ***conjunctival fornices***.

Note: The *palpebral conjunctiva* is thick, opaque, highly vascular and adherent to the tarsal plate. The *bulbar conjunctiva* covers the sclera. It is thin, transparent and loosely attached to the eyeball. Over the cornea, it is represented by the anterior epithelium of the cornea.

Flowchart 2.6: Nerve supply of the lacrimal gland


Parasympathetic fibres
Lacrimatory nucleus
Facial nerve
Nervus intermedius
Geniculate ganglion
Greater petrosal nerve
Pterygopalatine ganglion
Relay
Postganglionic fibres
Sympathetic fibres
T1 segment of spinal cord
Superior cervical sympathetic ganglion
Relay
Postganglionic fibres
Plexus around internal carotid artery
Pterygopalatine ganglion
Zygomatic nerve
Zygomaticotemporal nerve
Lacrimal gland

Lacrimal Puncta

These are small openings on the lid margin at the top of the laminal papillae. ***Lacrimal papilla*** is a small conical projection at the medial end of free margin of the eyelids.

Lacrimal Canaliculi

These are one in each eyelid, and it is about 10 mm long. Each canaliculus begins at the lacrimal punctum. It has two parts:

1. Vertical part: 2 mm long
2. Horizontal part: 8 mm long

There is an ampulla (dilated part) in each canaliculus.

Lacrimal Sac

It is a membranous sac, 12 mm long and 5 mm wide, situated in the lacrimal groove behind the medial palpebral ligament. Its upper end is blind. The lower end is continuous with the nasolacrimal duct.

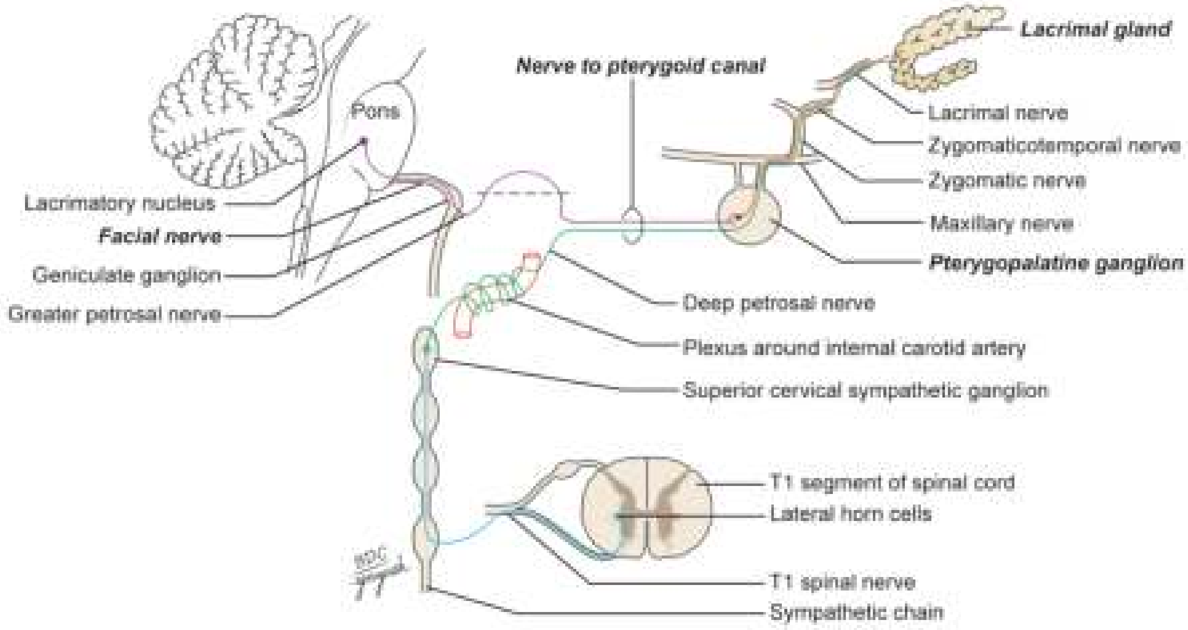

Lacrimal gland
Nerve to pterygoid canal
Pons
Lacrimal nerve
Zygomaticotemporal nerve
Zygomatic nerve
Lacrimatory nucleus
Maxillary nerve
Facial nerve
Pterygopalatine ganglion
Geniculate ganglion
Greater petrosal nerve
Deep petrosal nerve
Plexus around internal carotid artery
Superior cervical sympathetic ganglion
T1 segment of spinal cord
Lateral horn cells
T1 spinal nerve
Sympathetic chain

Fig. 2.31: Innervation of lacrimal gland (schematic representation, Purple line: Preganglionic parasympathetic fibres, Red line: Postganglionic parasympathetic fibres, Blue line: Preganglionic sympathetic fibres, Green line: Postganglionic sympathetic fibres, *Note*: Greater petrosal nerve enter the middle cranial fossa and enters the foramen lacerum where it forms nerve to pterygoid canal. Middle cranial fossa shown by black dotted line)

The sac is related anteriorly to the medial palpebral ligament and to the orbicularis oculi. Medially, the lacrimal groove separates it from the nose. Laterally, it is related to the lacrimal fascia and the lacrimal part of the orbicularis oculi which helps in dilatation of lacrimal sac for efficient drainage of lacrimal fluid (Fig. 2.30).

Nasolacrimal Duct

It is a membranous passage, 18 mm long. It begins at the lower end of the lacrimal sac, runs downwards, backwards and laterally and *opens into the inferior meatus of the nose*. A fold of mucous membrane called the ***valve of Hasner***, forms an imperfect valve at the lower end of the duct.

Note: ***Factors helping drainage of tears***:

1. Capillary action of lacrimal canaliculi
2. Blinking of eyelids that spreads the tears in conjunctival sac
3. Drying of tears
4. Inward direction of puncta during blinking
5. Conjunction of lacrimal part of orbicularis oculi pulls the lacrimal fascia that dilates the lacrimal sac.

CLINICAL ANATOMY

- Inflammation of the lacrimal sac is called ***dacryocystitis***.
- The ducts of lacrimal gland open through its palpebral part into the conjunctival sac. Because of this arrangement, the removal of palpebral part necessitates the removal of the orbital part as well.
- Excessive secretion of the lacrimal fluid overflowing on the cheeks is called ***epiphora***. Epiphora may result due to obstruction in the lacrimal fluid pathway, either at the level of punctum or canaliculi or nasolacrimal duct.

DISSECTION

On the lateral side of the upper lid, cut the palpebral fascia. This will show the presence of the lacrimal gland deep in this area. Its palpebral part is to be traced in the upper eyelid. On the medial ends of both the eyelids, look for lacrimal papilla. Palpate and dissect the medial palpebral ligament binding the medial ends of the eyelids. Try to locate the small lacrimal sac behind this ligament.

Competency:

AN43.4 Describe the development and developmental basis of congenital anomalies of face, palate, tongue, branchial apparatus, pituitary gland, thyroid gland and eye. (Development of face is given here. For the development of other structures, please refer to respective chapters.)

DEVELOPMENT OF FACE

The face develops from five mesodermal processes that appear in 4th week surrounding the stomodeum.

These processes are (Fig. 2.32):

1. Frontonasal process (unpaired)
2. Maxillary process (paired)
3. Mandibular process (paired).

Facial development takes place between 4th and 8th weeks.

The various parts of the face are derived as follows:

1. *Lower lip*: Bilateral mandibular process fuses in the midline to form a lower lip and jawbone.
2. *Upper lip*:
   - Central part (philtrum) of upper lip is derived from medial nasal process.

- Lateral parts of upper lip are derived from bilateral maxillary processes.

Note: The ectoderm (skin) of maxillary process overgrows and covers central part (philtrum) of the upper lip; hence, skin of the upper lip is supplied by maxillary nerve (Fig. 2.33).

3. Muscles of the face are derived from *second pharyngeal arch*, hence supplied by the facial nerve.

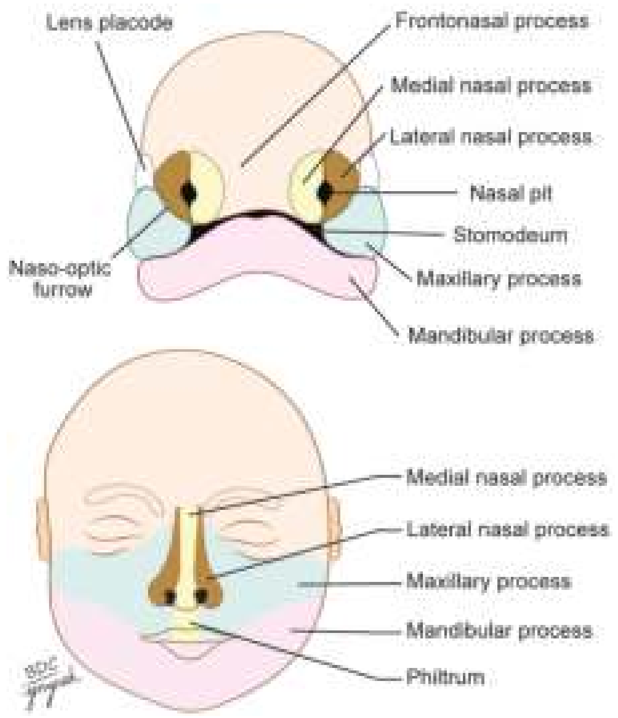

Lens placode
Frontonasal process
Medial nasal process
Lateral nasal process
Nasal pit
Stomodeum
Naso-optic furrow
Maxillary process
Mandibular process
Medial nasal process
Lateral nasal process
Maxillary process
Mandibular process
Philtrum
BDC gogiah

Fig. 2.32: Development of the face

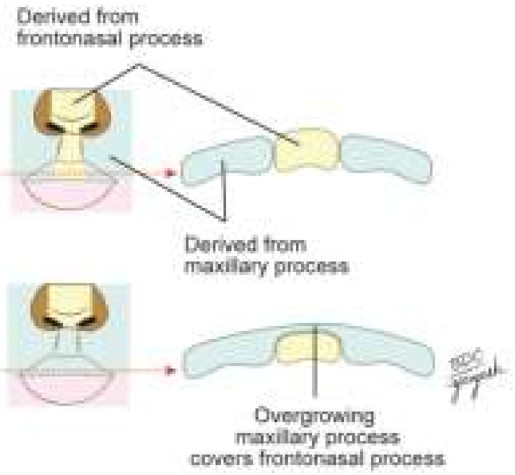

Derived from frontonasal process
Derived from maxillary process
Overgrowing maxillary process covers frontonasal process
BDC gogiah

Fig. 2.33: Formation of the upper lip. The ectoderm of the maxillary process overgrows the frontonasal process. Hence, skin of the upper lip is supplied by the maxillary nerve

4. *Cheeks*: The maxillary and mandibular processes undergo fusion from the lateral side and form smaller stomodeum or normal oral fissure, where fused part forms cheeks.
5. External nose is derived as follows:
   - Bridge of nose from frontonasal process.
   - Dorsum and tip of the nose from fused medial nasal processes.
   - Ala of nose from lateral nasal processes.
   - Anterior nares (nostrils) from nasal pit.
   - Nasal cavity from nasal sacs.
   - Posterior nares (choanae) from rupture of bucconasal membrane.

VIDEO

Video 3.2 Scalp and Face: Scalp, Face

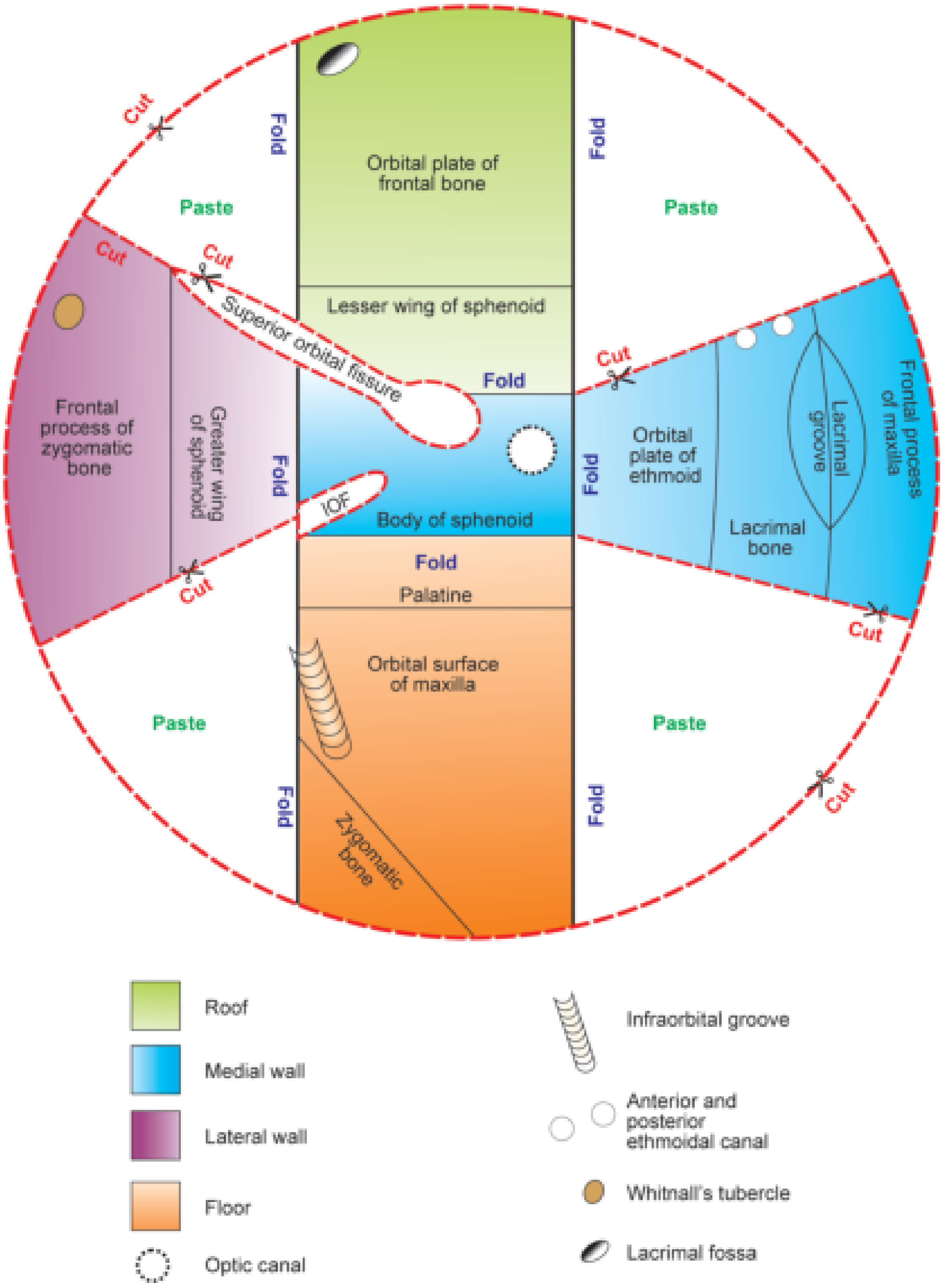
Facts to Remember

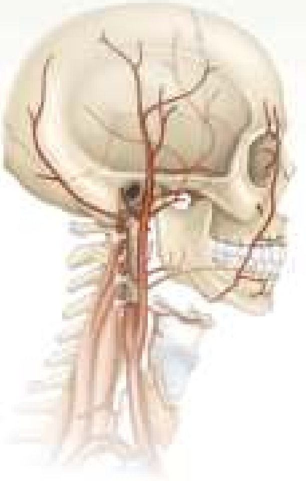
- Caput succedaneum is the most common form of birth trauma of the scalp.
- Impulses from skin of the face reach the three branches of trigeminal nerve, whereas the muscles of facial expression are supplied by the facial nerve.
- Facial nerve though courses through the parotid gland, does not give any branch to the largest salivary gland.
- Buccinator is an accessory muscle of mastication, as it prevents food entering the vestibule of mouth.
- Part of the face between anterior nares and upper lip is called 'dangerous area of face' as the facial vein communicates with cavernous venous sinus situated in the cranial cavity. Any infection from this part of face can infect the intracranial venous sinus, i.e. cavernous sinus.
- Levator palpebrae superioris is supplied partly by oculomotor nerve and partly by sympathetic fibres.
- The facial muscles are subcutaneous in position and represents morphologically remnants of panniculus carnosus. Platysma helps in loosening the tight collar or tie.
- Eyelid contains Meibomian/tarsal glands, glands of Zeis, glands of Moll and glands of Wolfring and glands of Krause.

BDC's Anatomy e-book

1. Surface landmarks
2. Molecular regulation of development of face
3. Further reading
4. Viva voce questions

Right orbit seen from the front


Cut
Cut
Cut
Cut
Cut
Cut
Cut
Fold
Fold
Fold
Fold
Fold
Fold
Fold
Fold
Paste
Paste
Paste
Paste
Orbital plate of frontal bone
Lesser wing of sphenoid
Superior orbital fissure
Frontal process of zygomatic bone
Greater wing of sphenoid
IOF
Body of sphenoid
Orbital plate of ethmoid
Lacrimal groove
Frontal process of maxilla
Lacrimal bone
Palatine
Orbital surface of maxilla
Zygomatic bone
Roof
Medial wall
Lateral wall
Floor
Optic canal
Infraorbital groove
Anterior and posterior ethmoidal canal
Whitnall's tubercle
Lacrimal fossa



Chapter 3

Side of the Neck

The neck extends superiorly up to external occipital protuberance, superior nuchal line, mastoid process, angle of mandible and base or inferior border of mandible. Inferiorly, the neck extends up to spine of C7 vertebra, superior border of scapula, acromion, clavicle and suprasternal notch.

On observing the neck from the lateral side, it appears quadrangular in shape. This quadrilateral area of the side of the neck is divided into two triangular areas by the sternocleidomastoid muscle as large anterior and small posterior triangles.

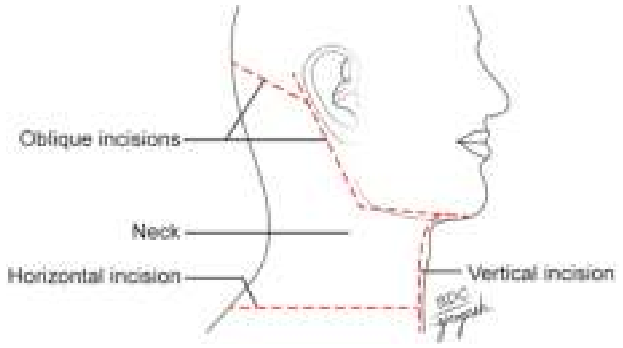


Fig. 3.1: Lines of dissection

LANDMARKS

1. ***Sternocleidomastoid*** muscle is seen prominently when the neck and chin are turned to the opposite side. The ridge raised by the muscle extends from the clavicle and sternum to the mastoid process (Fig. 3.1).
2. ***External jugular vein*** crosses the sternocleidomastoid obliquely, running downwards and backwards from near the auricle to the clavicle. It is better seen in old age.
3. ***Greater supraclavicular fossa*** lies above and behind the middle one-third of the clavicle. It overlies the cervical part of the brachial plexus and the third part of the subclavian artery.
4. ***Lesser supraclavicular fossa*** is a small depression between the sternal and clavicular parts of the sternocleidomastoid. It overlies the internal jugular vein.
5. ***Mastoid process*** is a large bony projection behind the auricle.
6. ***Transverse process of the atlas vertebra*** can be felt on deep pressure midway between the angle of the mandible and the mastoid process, immediately anteroinferior to the tip of the mastoid process.
7. The *4th cervical transverse process* is just palpable at the level of the upper border of the thyroid cartilage; and the *6th cervical transverse process* is at the level of the cricoid cartilage.
8. The anterior tubercle of the *transverse process of the 6th cervical vertebra* is the largest of all such processes and is called the ***carotid tubercle*** of Chassaignac. The common carotid artery can be best pressed against this tubercle, deep to the anterior border of the sternocleidomastoid muscle.
9. The ***anterior border of the trapezius muscle*** becomes prominent on elevation of the shoulder against resistance.

BOUNDARIES

The side of the neck is roughly quadrilateral in outline (Fig. 3.2).

It is *bounded as follows:*

Anteriorly: Anterior median line
Posteriorly: Anterior border of trapezius
Superiorly: Base of mandible
A line joining angle of the mandible to mastoid process
Superior nuchal line
Inferiorly: Clavicle.

This quadrilateral space is divided obliquely by the sternocleidomastoid muscle into the *anterior and posterior triangles* (Fig. 3.3).

SKIN

The skin of the neck is supplied by the C2 to C4 spinal nerves.

The anterolateral part is supplied by anterior primary rami through

1. Transverse/anterior cutaneous nerve (C2, C3)
2. Great auricular nerve (C2, C3)

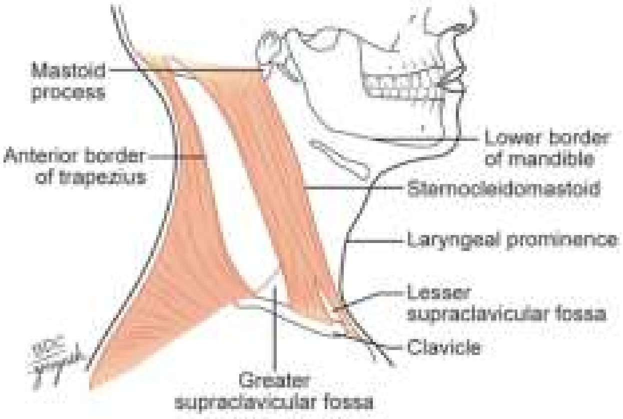


Fig. 3.2: Boundaries of the side of neck

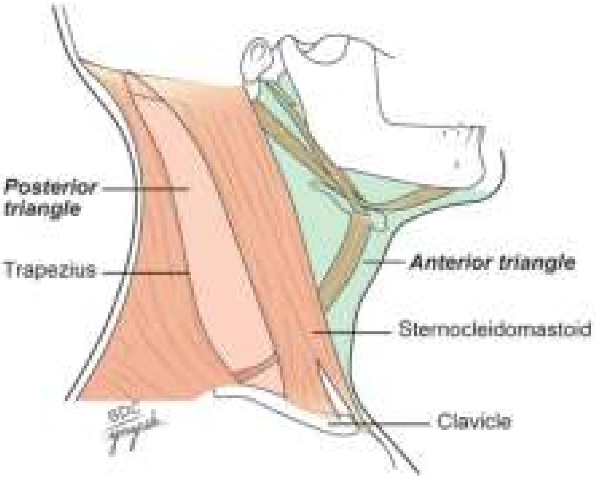


Fig. 3.3: Side of neck divided into anterior and posterior triangles

3. Lesser occipital nerve (C2)
4. Supraclavicular nerves (C3, C4).

A broad band of skin over the posterior part is supplied by dorsal or posterior primary rami (*see* Fig. 2.21).

Note: The 1st cervical spinal nerve has no cutaneous distribution. The C5, C6, C7, C8 and T1 nerves supply the upper limb through the brachial plexus; and, therefore, do not supply the neck. The territory of C4 nerve extends into the pectoral region through the supraclavicular nerves and meets T2 dermatome at the level of the 2nd costal cartilage.

SUPERFICIAL FASCIA

Superficial fascia contains:
1. Areolar tissue
2. Platysma
3. Cutaneous nerves
4. Superficial veins
5. *Lymph vessels, lymph nodes* and small arteries.

CLINICAL ANATOMY

The surgeon has to stitch platysma muscle separately so that skin does not adhere to deeper neck muscles, otherwise the skin will get an ugly scar.

DISSECTION

Give a median incision from the chin downwards towards the suprasternal notch situated above the manubrium of sternum.

Make one incision in the skin of base of mandible. Continue it by oblique incision along posterior border of ramus of mandible up to mastoid process and further along the superior nuchal line till the external occipital protuberance.

One incision is given along the upper border of clavicle (Fig. 3.1). Reflect only the skin up towards the anterior border of trapezius muscle.

Platysma, a part of the subcutaneous muscle is visible. Reflect the platysma towards the mandible. Identify the anterior or transverse cutaneous nerve of the neck in the upper part of superficial fascia. Anterior jugular vein running vertically close to the median plane is also encountered. Remove the superficial fascia till the deep fascia of neck is seen (Fig. 3.1).

External jugular vein is seen above the clavicle. To open up the suprasternal space, make a horizontal incision just above the sternum. Extend this incision along the anterior border of sternocleidomastoid muscle for 3–4 cm. Reflect the superficial lamina to expose the suprasternal space and identify its contents.

Define the attachments of investing layer, pretracheal layer, prevertebral layer and carotid sheath.

Competency:
AN35.1 Describe the parts, extent, attachments, modifications of deep cervical fascia.

DEEP CERVICAL FASCIA (FASCIA COLLI)

The deep cervical fascia is the most important structure that holds the structures in the neck in place. It separates neurovascular bundles, prevents compression of vessels, trachea and oesophagus and prevents spread of infection. The deep fascia of the neck is condensed to form the following layers:
1. Investing layer
2. Pretracheal fascia
3. Prevertebral fascia
4. Carotid sheath
5. Buccopharyngeal fascia
6. Pharyngobasilar fascia.

INVESTING LAYER

It lies deep to the platysma and surrounds the neck like a collar. It forms the roof of the posterior triangle of the neck (Figs 3.4 to 3.8).

Attachments and Tracings

Superiorly

a. External occipital protuberance
b. Superior nuchal line

c. Mastoid process, styloid process
d. External acoustic meatus, tympanic plate
e. Base of the mandible.

Note: Between the angle of the mandible and the mastoid process, the fascia splits to enclose the parotid gland (Fig. 3.5).

a. The ***superficial lamina***, named ***parotid fascia***, is thick and dense and is attached to the zygomatic arch.
b. The ***deep lamina*** is thin and is attached to the styloid process, the tympanic plate and the mandible (*see* Fig. 5.2). Between the styloid process and the angle of the mandible, the deep lamina is thick and forms the ***stylomandibular ligament*** which separates the parotid gland from the submandibular gland, and is pierced by the external carotid artery.

   The superficial lamina is attached to lower border of body of mandible and deep lamina to the mylohyoid line.

Inferiorly

a. Spine of scapula
b. Acromion process
c. Clavicle
d. Manubrium.

Note: The fascia splits to enclose the suprasternal and supraclavicular spaces (Fig. 3.5).

Posteriorly

a. Ligamentum nuchae and
b. Spine of C7 vertebra.

Anteriorly

a. Symphysis menti
b. Hyoid bone.

Both above and below the hyoid bone, it is continuous with the fascia of the opposite side.

Features of Investing Layer

1. The investing layer of deep cervical fascia *splits* to enclose (Figs 3.5 to 3.7):
   a. *Muscles*: Trapezius and sternocleidomastoid.
   b. *Salivary glands*: Parotid and submandibular
   c. *Spaces*: Suprasternal and supraclavicular.
2. ***Suprasternal space*** or space of Burns contains:
   a. Sternal heads of the right and left sternocleidomastoid muscles (Fig. 3.8),
   b. Jugular venous arch,
   c. Lymph node and
   d. Interclavicular ligament.
3. ***Supraclavicular space*** lying above middle 1/3rd of clavicle is traversed by (Fig. 3.6):
   a. External jugular vein,
   b. Supraclavicular nerves and
   c. Cutaneous vessels, including lymphatics.
4. It also forms *pulleys* to bind the tendons of the digastric and omohyoid muscles.
5. Forms roof of anterior and posterior triangles.
6. Forms stylomandibular ligament (Fig. 3.6) and parotidomasseteric fascia.

Note: **Rule of 2** for investing layer:

- Enclosed muscles: Trapezius, SCM
- Roofs of anterior and posterior triangles
- Enclosed glands: Submandibular and parotid
- Enclosed spaces: Suprasternal and supraclavicular
- Pullies for: Omohyoid and digastric.

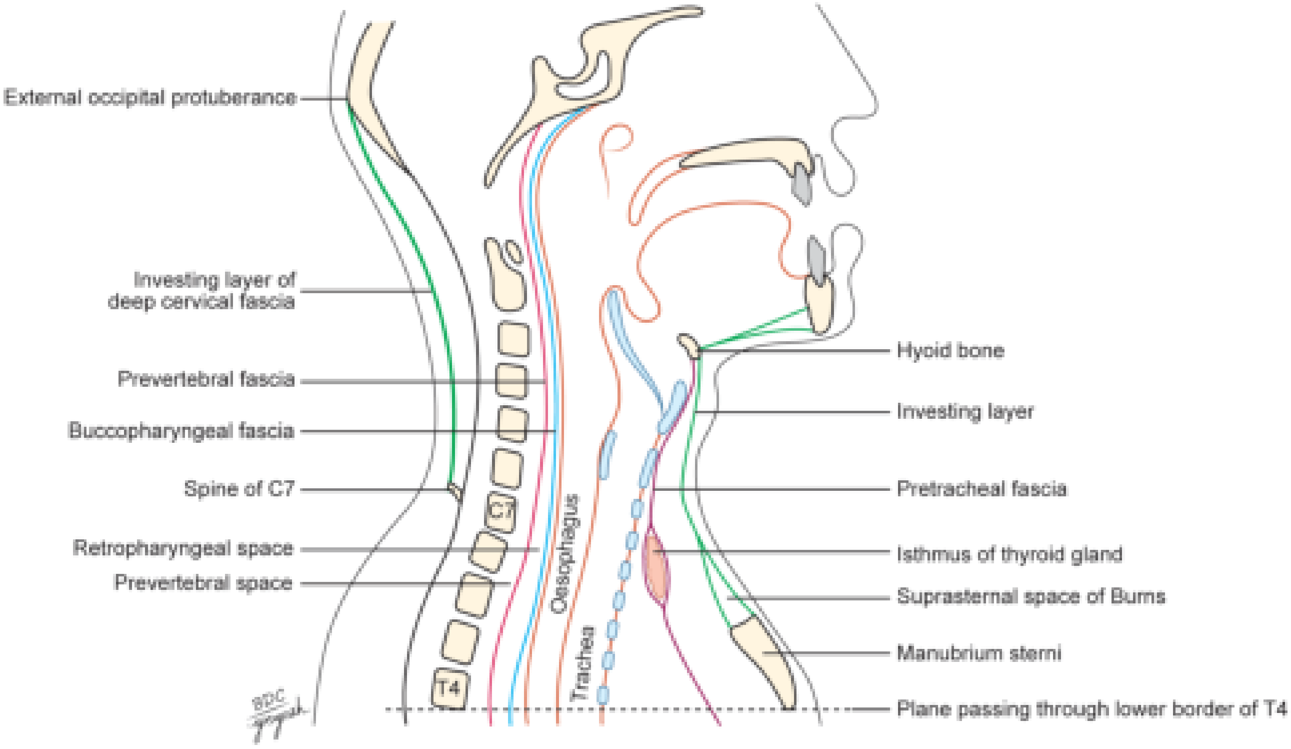

External occipital protuberance
Investing layer of deep cervical fascia
Prevertebral fascia
Buccopharyngeal fascia
Spine of C7
Retropharyngeal space
Prevertebral space
C7
T4
Oesophagus
Trachea
Hyoid bone
Investing layer
Pretracheal fascia
Isthmus of thyroid gland
Suprasternal space of Burns
Manubrium sterni
Plane passing through lower border of T4

Fig. 3.4: Vertical extent of the first three layers of the deep cervical fascia

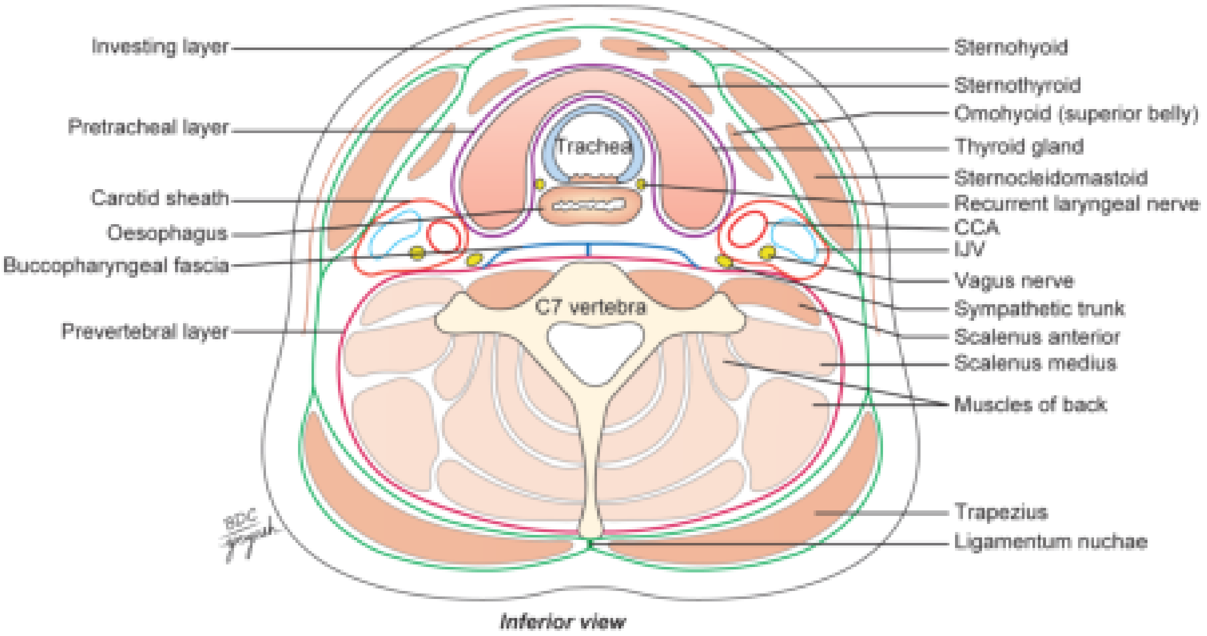

Investing layer
Pretracheal layer
Carotid sheath
Oesophagus
Buccopharyngeal fascia
Prevertebral layer
Trachea
C7 vertebra
Sternohyoid
Sternothyroid
Omohyoid (superior belly)
Thyroid gland
Sternocleidomastoid
Recurrent laryngeal nerve
CCA
IJV
Vagus nerve
Sympathetic trunk
Scalenus anterior
Scalenus medius
Muscles of back
Trapezius
Ligamentum nuchae
BDC
Inferior view

Fig. 3.5: Transverse section through neck at the level of the 7th cervical vertebra to show the horizontal disposition of the three layers of deep cervical fascia (CCA: Common carotid artery; IJV: Internal jugular vein)

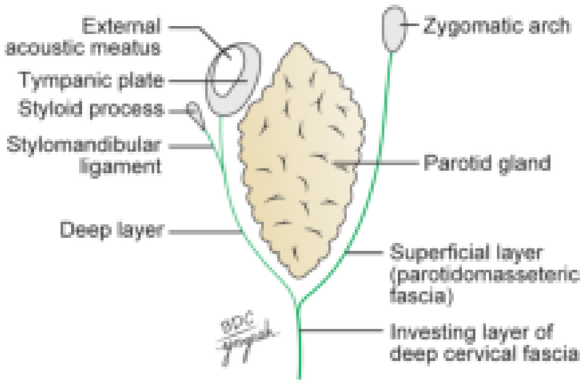

External acoustic meatus
Tympanic plate
Styloid process
Stylomandibular ligament
Deep layer
Zygomatic arch
Parotid gland
Superficial layer (parotidomasseteric fascia)
Investing layer of deep cervical fascia
BDC

Fig. 3.6: Investing layer of the deep cervical fascia enclosing parotid gland (right, coronal section passing behind the ramus of mandible, posterior view)

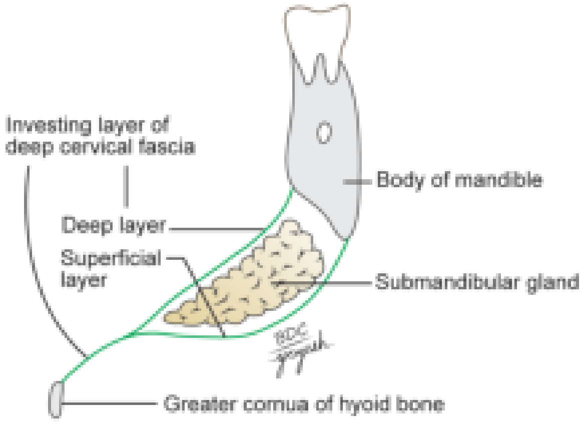

Investing layer of deep cervical fascia
Deep layer
Superficial layer
Body of mandible
Submandibular gland
Greater cornua of hyoid bone
BDC

Fig. 3.7: Investing layer of the deep cervical fascia enclosing the submandibular gland (coronal section passing through the body of mandible, posterior view)

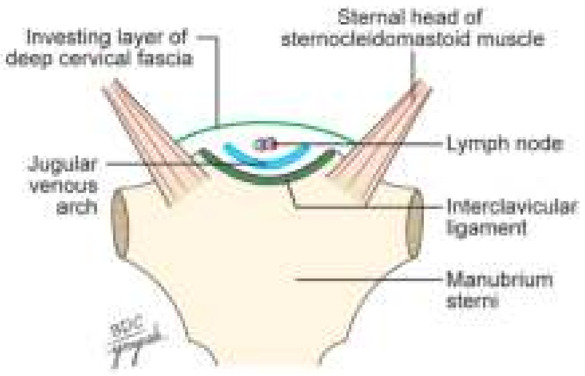

Investing layer of deep cervical fascia
Sternal head of sternocleidomastoid muscle
Jugular venous arch
Lymph node
Interclavicular ligament
Manubrium sterni
BDC

Fig. 3.8: Contents of suprasternal space

CLINICAL ANATOMY

- ***Painful parotid swelling***: Parotid swellings are very painful due to the unyielding nature of parotid fascia.
- While excising the submandibular salivary gland, the external carotid artery should be secured before dividing it, otherwise it may retract through the stylomandibular ligament and cause serious bleeding. This figure also shows the superior attachment of investing layer of deep cervical fascia to tympanic plate and styloid process.
- Division of the external jugular vein in the supraclavicular space may cause air embolism and consequent death because the cut ends of the vein are prevented from contraction and closure by the fascia, attached firmly to the vein.

PRETRACHEAL FASCIA

The importance of this fascia is that it encloses and suspends the thyroid gland and forms its false capsule (Fig. 3.2). It is continuous with buccopharyngeal fascia.

Attachments and Tracings

Superiorly

1. Hyoid bone in the median plane
2. Oblique line of thyroid cartilage—laterally
3. Cricoid cartilage—more laterally.

Inferiorly

Below the thyroid gland, it encloses the inferior thyroid veins, passes behind the brachiocephalic veins and finally blends with the arch of the aorta and fibrous pericardium.

On Either Side

It forms the front of the carotid sheath and fuses with the fascia deep to the sternocleidomastoid (Fig. 3.3).

Features of Pretracheal Fascia

1. The posterior layer of the thyroid capsule is thick. On either side, it forms a ***suspensory ligament*** for the thyroid gland known as ***ligament of Berry***. The ligaments are attached chiefly to the cricoid cartilage, and may extend to the thyroid cartilage. They support the thyroid gland and do not let it sink into the mediastinum. The capsule of the thyroid is very weak along the posterior borders of the lateral lobes.
2. Permits movement of trachea: The fascia provides a slippery surface for free movements of the trachea during swallowing.

CLINICAL ANATOMY

- Neck infections in front of the pretracheal fascia may bulge in the suprasternal area or extend down into the anterior mediastinum.
- The thyroid gland and all thyroid swellings move with deglutition because the thyroid is attached to cartilages of the larynx by the suspensory ligaments of Berry.
- Extension of neck infection: As the pretracheal fascia extends into the superior mediastinum, a pus (infection) in front of the pretracheal fascia may extend into the superior mediastinum.

PREVERTEBRAL FASCIA

It lies in front of the prevertebral muscles and forms the floor of the posterior triangle of the neck (Fig. 3.4).

Attachments and Tracings

Superiorly

It is attached to the base of the skull.

Inferiorly

It extends into the superior mediastinum and blends with the anterior longitudinal ligament and body of thoracic vertebrae.

Anteriorly

It is separated from the pharynx and buccopharyngeal fascia by the ***retropharyngeal space***. In the lower part of neck, prevertebral and buccopharyngeal fasciae fuse. Lymph nodes lie in the retropharyngeal space.

Laterally

It lies deep into the trapezius and is attached to fascia of sternocleidomastoid muscle.

Features of Prevertebral Fascia

1. The trunks of brachial plexuses lie behind the prevertebral fascia between scalenus anterior and scalenus medius muscles. The fascia is pierced by the four cutaneous branches of the cervical plexus.
2. As the trunks of the brachial plexus and the subclavian artery pass laterally through the interval between the scalenus anterior and the scalenus medius, they carry with them a covering of the prevertebral fascia known as the ***axillary sheath*** which extends into the axilla. The subclavian and axillary veins lie outside the sheath and as a result, they can dilate during increased venous return from the limb.
3. Fascia provides a fixed base for the movements of the pharynx, the oesophagus and the carotid sheaths during movements of the neck and during swallowing.

Spaces in relation to prevertebral fascia (Fig. 3.9)

1. ***Retropharyngeal space*** lies between the prevertebral fascia and buccopharyngeal fascia. It allows the expansion of the pharynx during swallowing.

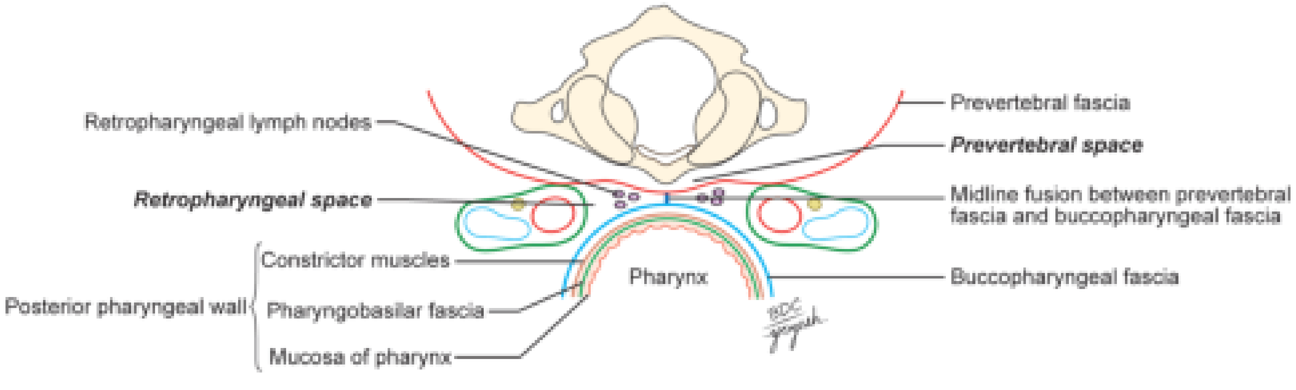


Fig. 3.9: Spaces in relation to prevertebral fascia

2. ***Space of Gillette*** is the right or left parts of the retropharyngeal space divided by median fibrous raphe. This space contains retropharyngeal nodes.
3. ***Prevertebral space*** lies behind the prevertebral fascia, anterior to the vertebral bodies.

CLINICAL ANATOMY

- ***Neck infections*** behind the prevertebral fascia arise usually from tuberculosis of the cervical vertebrae or cervical caries. Pus produced as a result may extend in various directions. It may pass forwards forming a chronic retropharyngeal abscess which may form a bulging in the posterior wall of the pharynx, in the median plane. The pus may extend laterally through the axillary sheath and point in the posterior triangle, or in the lateral wall of the axilla. It may extend downwards into the superior mediastinum, where its descent is limited by fusion of the prevertebral fascia to the fourth thoracic vertebra.
- Neck infections in front of the prevertebral fascia in the retropharyngeal space usually arise from suppuration, i.e. formation of pus in the retropharyngeal lymph nodes. The pus forms an acute retropharyngeal abscess which bulges forwards in the paramedian position due to fusion of the buccopharyngeal fascia to the prevertebral fascia in the median plane. The infection may extend down through the superior mediastinum into the posterior mediastinum.

BUCCOPHARYNGEAL FASCIA

This fascia covers all the constrictor muscles externally and extends onto the superficial aspect of the buccinator muscle.

It is attached to pharyngeal tubercle superiorly. This fascia fuses with the periosteum on the posterior part of alveolar process of maxilla. Retropharyngeal space lies posterior to buccopharyngeal fascia.

PHARYNGOBASILAR FASCIA

This fascia is especially thickened between the upper border of superior constrictor muscle and the base of the skull. It lies deep to the pharyngeal muscles.

Note: ***Alar fascia*** is a layer of loose areolar tissue that lies between buccopharyngeal and prevertebral fascia. **Dangerous space** lies between alar fascia and prevertebral fascia, whereas *prevertebral space* lies between prevertebral fascia and vertebrae.

CAROTID SHEATH

Carotid sheath is a derivative of the deep cervical fascia. It is a condensation of the fibroareolar tissue around the main vessels of the neck (Figs 3.10a and b, Flowchart 3.1)

Formation: It is formed on anterior aspect by pretracheal fascia and on posterior aspect by prevertebral fascia.

Contents:

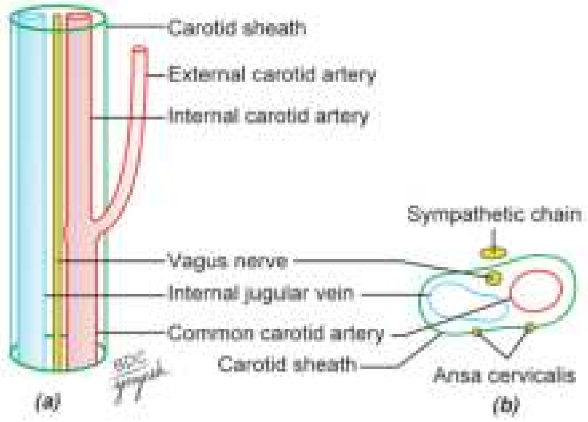
1. Common and internal carotid arteries
2. Internal jugular vein
3. Vagus (X) nerve
4. IX, XI, XII cranial nerves in the upper part (they pierce the carotid sheath at different points).

Relations:

1. The ansa cervicalis lies embedded in the anterior wall of the carotid sheath (Figs 3.10b).
2. The cervical sympathetic chain lies behind the sheath, plastered to the prevertebral fascia (Fig. 3.10b).
3. The sheath is overlapped by the anterior border of the sternocleidomastoid, and is fused to the layers of the deep cervical fascia.

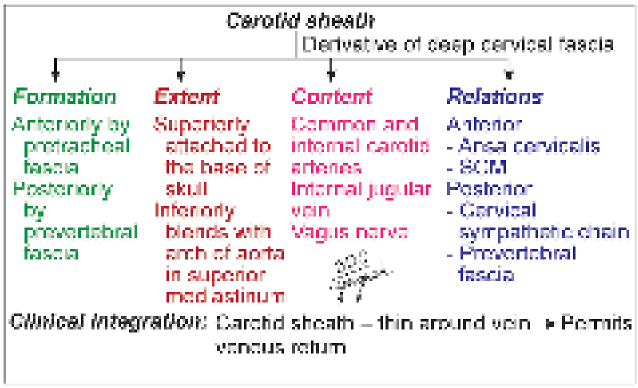
CLINICAL ANATOMY

- Carotid sheath is thick around the arteries and thin around the vein. This permits the expansion of internal jugular vein during increased venous return.
- Wall of the carotid sheath is excised to remove lymph nodes adherent to the internal jugular vein during block dissection of neck. It is usually done in cancers or tuberculosis.


Carotid sheath
External carotid artery
Internal carotid artery
Sympathetic chain
Vagus nerve
Internal jugular vein
Common carotid artery
Carotid sheath
Ansa cervicalis
(a)
(b)

Figs 3.10a and b: Carotid sheath with its contents: (a) Surface view and (b) section view

Flowchart 3.1: Carotid sheath


Carotid sheath
Derivative of deep cervical fascia
Formation
Anteriorly by pretracheal fascia
Posteriorly by prevertebral fascia
Extent
Superiorly attached to the base of skull
Inferiorly blends with arch of aorta in superior mediastinum
Content
Common and internal carotid arteries
Internal jugular vein
Vagus nerve
Relations
Anterior
- Ansa cervicalis
- SCM
Posterior
- Cervical sympathetic chain
- Prevertebral fascia
Clinical integration: Carotid sheath – thin around vein ► Permits venous return

(SCM: Sternocleidomastoid)

Competency:
AN35.10 Describe the fascial spaces of neck/pharynx.

PHARYNGEAL SPACES

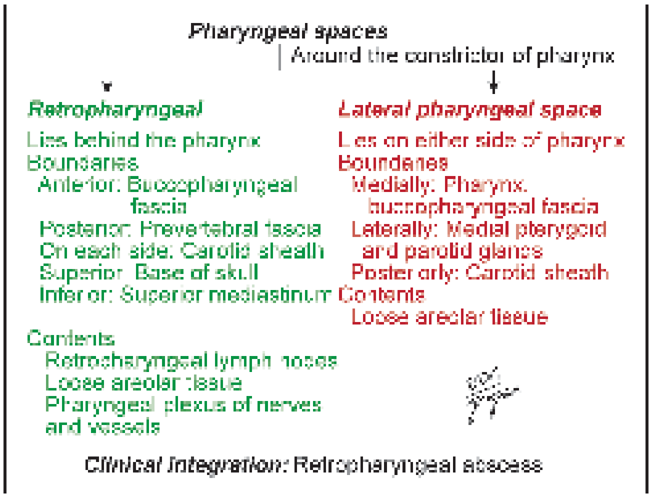
RETROPHARYNGEAL SPACE (Flowchart 3.2)

Situation:	Dead space behind pharynx
Function:	Acts as a bursa for expansion of pharynx during deglutition
Boundaries:	
Anterior:	Buccopharyngeal fascia
Posterior:	Prevertebral fascia. The two get fused.
Sides:	Carotid sheath
Superior:	Base of skull
Inferior:	Open and continuous with superior mediastinum.
Contents:	Retropharyngeal lymph nodes, pharyngeal plexus of vessels and nerves, loose areolar tissue.
Clinical anatomy:	Pus collection due to lymph node abscess which lies in paramedian position. It should be differentiated from cold abscess of spine of cervical vertebrae which is seen in median plane.

LATERAL PHARYNGEAL SPACE (Flowchart 3.2)

Situation:	Side of pharynx
Boundaries:	
Medial:	Pharynx
Posterolateral:	Parotid gland
Anterolateral:	Medial pterygoid
Posterior:	Carotid sheath
Contents:	Branches of maxillary artery Fibrofatty tissue
Clinical anatomy:	Pus collection/Ludwig's angina

Flowchart 3.2: Pharyngeal spaces


Pharyngeal spaces
Around the constrictor of pharynx
Retropharyngeal
Lies behind the pharynx
Boundaries
Anterior: Buccopharyngeal fascia
Posterior: Prevertebral fascia
On each side: Carotid sheath
Superior: Base of skull
Inferior: Superior mediastinum
Contents
Retropharyngeal lymph nodes
Loose areolar tissue
Pharyngeal plexus of nerves and vessels
Lateral pharyngeal space
Lies on either side of pharynx
Boundaries
Medially: Pharynx, buccopharyngeal fascia
Laterally: Medial pterygoid and parotid glands
Posteriorly: Carotid sheath
Contents
Loose areolar tissue
Clinical Integration: Retropharyngeal abscess

Competency:
AN29.2 Describe and demonstrate attachments, nerve supply, relations and actions of sternocleidomastoid.

STERNOCLEIDOMASTOID (STERNOMASTOID) MUSCLE

It is also called sternomastoid. It is a long flat strap of muscle that extends obliquely across the side of the neck. It is enclosed within the investing layer of deep cervical fascia (Plate 3.1, Flowchart 3.3).

Origin

Sternal head: It is tendinous and arises from the superolateral part of the front of the manubrium sterni (Fig. 3.1c).

Clavicular head: It is musculotendinous and arises from the medial one-third of the superior surface of the clavicle. It passes deep to the sternal head, and the two heads blend below the middle of the neck. Between the two heads, there is a small triangular depression or the lesser supraclavicular fossa, overlying the internal jugular vein.

Insertion

It is inserted:

1. By a thick tendon into the lateral surface of *mastoid process*, from its tip to superior border.
2. By a thin aponeurosis into the lateral two-thirds of the *superior nuchal line* of the occipital bone.

Nerve Supply

1. Spinal accessory nerve provides the motor supply. It passes through the muscle (Fig. 3.10).
2. Branches from the ventral rami of C2 and C3 are proprioceptive.

Blood Supply

Arterial supply—one branch each from superior thyroid artery and suprascapular artery and, two branches from the occipital artery supply the big muscle. Veins follow the arteries.

Flowchart 3.3: Sternocleidomastoid

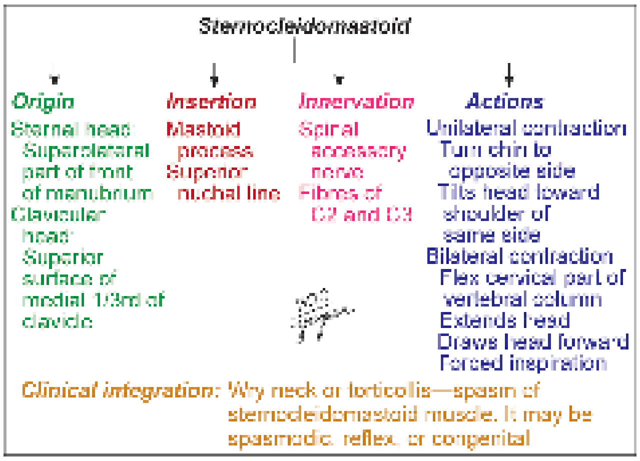
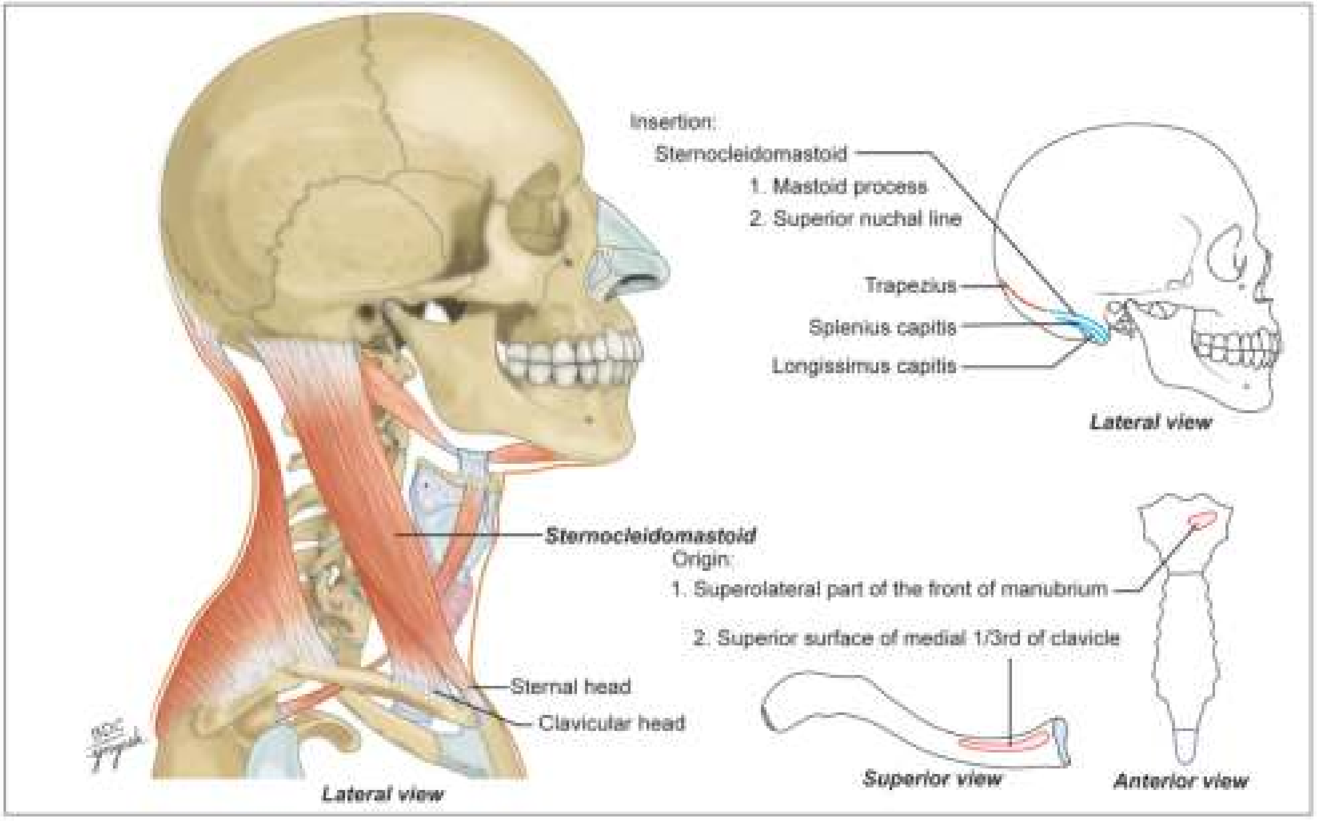

Sternocleidomastoid
Origin
Sternal head: Superolateral part of front of manubrium
Clavicular head: Superior surface of medial 1/3rd of clavicle
Insertion
Mastoid process
Superior nuchal line
Innervation
Spinal accessory nerve
Fibres of C2 and C3
Actions
Unilateral contraction
Turn chin to opposite side
Tilts head toward shoulder of same side
Bilateral contraction
Flex cervical part of vertebral column
Extends head
Draws head forward
Forced inspiration
Clinical integration: Wry neck or torticollis—spasm of sternocleidomastoid muscle. It may be spasmodic, reflex, or congenital

Plate 3.1: Sternocleidomastoid muscle


Insertion:
Sternocleidomastoid
1. Mastoid process
2. Superior nuchal line
Trapezius
Splenius capitis
Longissimus capitis
Lateral view
Sternocleidomastoid
Origin:
1. Superolateral part of the front of manubrium
2. Superior surface of medial 1/3rd of clavicle
Sternal head
Clavicular head
Lateral view
Superior view
Anterior view

Actions

1. When one muscle contracts:
   a. It turns the chin to the opposite side.
   b. It can also tilt the head towards the shoulder of same side.
2. When both muscles contract together:
   a. They draw the head forwards, as in eating and in lifting the head from a pillow.
   b. With the longus colli, they flex the neck against resistance.
   c. It also helps in forced inspiration.

Relations of Sternocleidomastoid

The sternocleidomastoid is enclosed in the investing layer of deep cervical fascia. It is pierced by the accessory nerve and by the four sternocleidomastoid arteries. It has the following relations.

Superficial

1. Skin
2. Superficial fascia, superficial lamina of the deep cervical fascia
3. Platysma
4. External jugular vein and superficial cervical lymph nodes lying along the vein
5. Great auricular, transverse or anterior cutaneous, medial supraclavicular nerves and lesser occipital nerves
6. The parotid gland overlaps the muscle.

Deep

1. *Bones and joints*: Mastoid process and sternoclavicular joint
2. Carotid sheath
3. *Muscles*:
   a. Sternohyoid
   b. Sternothyroid
   c. Omohyoid
   d. Three scaleni
   e. Levator scapulae
   f. Splenius capitis
   g. Longissimus capitis
   h. Posterior belly of digastric.
4. *Arteries*:
   a. Common carotid
   b. Internal carotid
   c. External carotid
   d. Sternocleidomastoid arteries, two from the occipital artery, one from the superior thyroid, one from the suprascapular
   e. Occipital
   f. Subclavian
   g. Suprascapular
   h. Transverse cervical
5. *Veins*:
   a. Internal jugular
   b. Anterior jugular
   c. Facial
   d. Lingual

6. *Nerves*:
   a. Vagus/X
   b. Parts of IX, XI, XII. Spinal root of XI leaves the SCM at middle of its posterior border to lie in posterior triangle
   c. Cervical plexus
   d. Upper part of brachial plexus
   e. Phrenic
   f. Ansa cervicalis
7. Lymph nodes, superficial and deep cervical.

Competency:
AN29.4 Explain anatomical basis of wry neck.

CLINICAL ANATOMY

- Fascia of supraclavicular space is pierced by external jugular vein to drain into subclavian vein (Fig. 3.6).
- ***Torticollis*** is a deformity in which the head is bent to one side and the chin points to the other side. This is a result of spasm or contracture of the muscles supplied by the spinal accessory nerve, these being the sternocleidomastoid and trapezius. Although there are many varieties of torticollis depending on the causes; the common types are:
  a. Rheumatic torticollis due to exposure to cold or draught.
  b. Reflex torticollis due to inflamed or suppurating cervical lymph nodes which irritate the spinal accessory nerve.
  c. Congenital torticollis due to birth injury (Fig. 3.11)
- ***Wry neck:*** Shortening of the muscle fibres due to intravascular clotting of veins within the muscle. It usually occurs during difficult delivery of the baby.

Competency:
AN29.1 Describe and demonstrate the boundaries, subdivisions and contents of posterior triangle of neck.

POSTERIOR TRIANGLE

The posterior triangle is a space on the side of the neck situated behind the sternocleidomastoid muscle (Fig. 3.12, Flowchart 3.4).

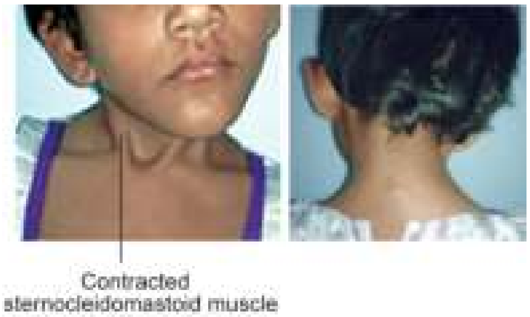

Contracted
sternocleidomastoid muscle

Fig. 3.11: Congenital torticollis

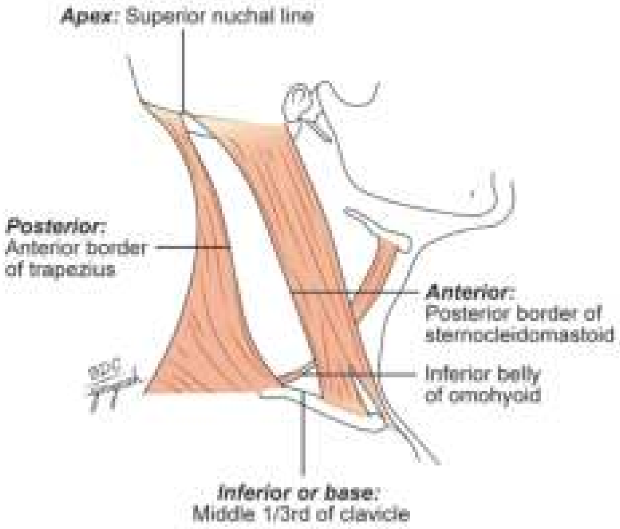

Apex: Superior nuchal line
Posterior: Anterior border of trapezius
Anterior: Posterior border of sternocleidomastoid
Inferior belly of omohyoid
Inferior or base: Middle 1/3rd of clavicle

Fig. 3.12: Posterior triangle: Boundaries

Boundaries

Anterior: Posterior border of sternocleidomastoid

Posterior: Anterior border of trapezius.

Inferior or base: Middle 1/3rd of clavicle.

Apex: Lies on the superior nuchal line where the trapezius and sternocleidomastoid meet.

Roof

The roof is formed by the (Plate 3.2, Fig. 3.13)

1. *Skin*

Flowchart 3.4: Posterior triangle

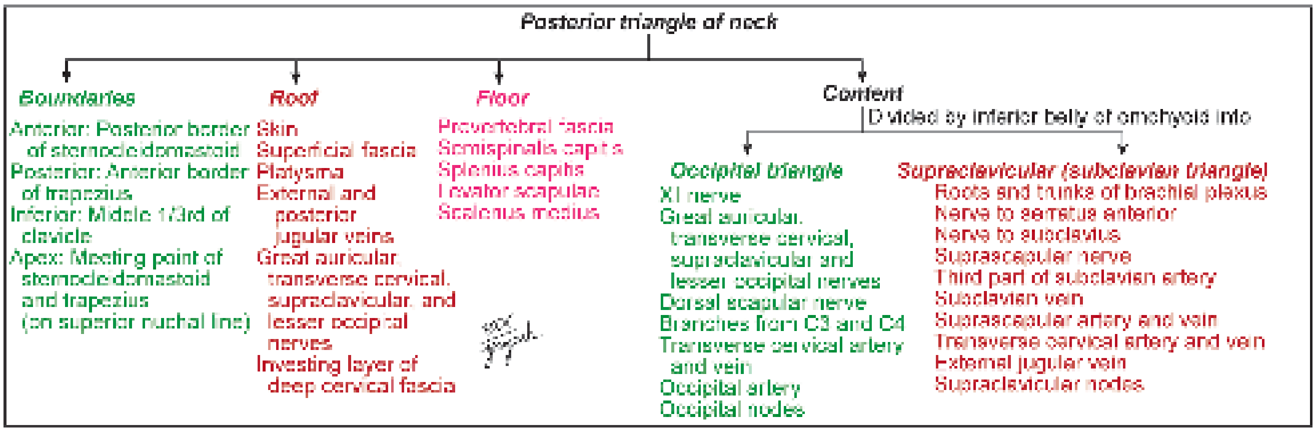
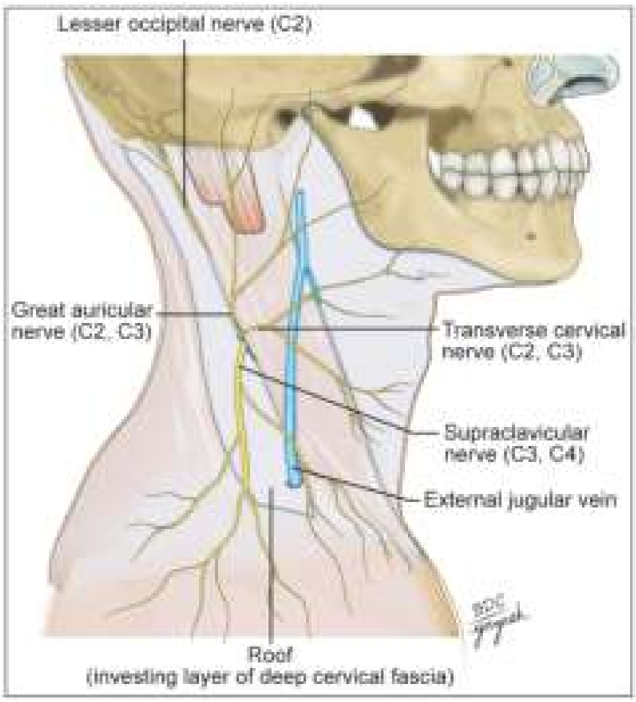

Posterior triangle of neck
Boundaries
Anterior: Posterior border of sternocleidomastoid
Posterior: Anterior border of trapezius
Inferior: Middle 1/3rd of clavicle
Apex: Meeting point of sternocleidomastoid and trapezius (on superior nuchal line)
Roof
Skin
Superficial fascia
Platysma
External and posterior jugular veins
Great auricular, transverse cervical, supraclavicular, and lesser occipital nerves
Investing layer of deep cervical fascia
Floor
Prevertebral fascia
Semispinalis capitis
Splenius capitis
Levator scapulae
Scalenus medius
Content
Divided by inferior belly of omohyoid into
Occipital triangle
XI nerve
Great auricular, transverse cervical, supraclavicular and lesser occipital nerves
Dorsal scapular nerve
Branches from C3 and C4
Transverse cervical artery and vein
Occipital artery
Occipital nodes
Supraclavicular (subclavian triangle)
Roots and trunks of brachial plexus
Nerve to serratus anterior
Nerve to subclavius
Suprascapular nerve
Third part of subclavian artery
Subclavian vein
Suprascapular artery and vein
Transverse cervical artery and vein
External jugular vein
Supraclavicular nodes

Plate 3.2: Structures piercing the roof of the posterior triangle


Lesser occipital nerve (C2)
Great auricular nerve (C2, C3)
Transverse cervical nerve (C2, C3)
Supraclavicular nerve (C3, C4)
External jugular vein
Roof
(investing layer of deep cervical fascia)
BDC

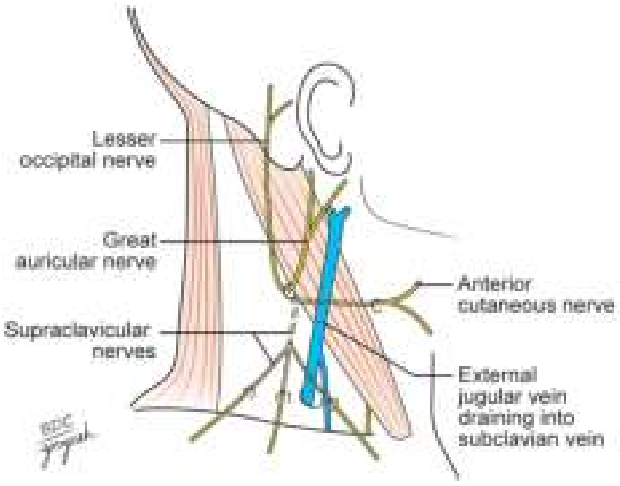

Lesser occipital nerve
Great auricular nerve
Supraclavicular nerves
Anterior cutaneous nerve
External jugular vein draining into subclavian vein
BDC

Fig. 3.13: Roof of the posterior triangle

2. Superficial fascia containing:
    a. Platysma
    b. External jugular and posterior external jugular veins
    c. Parts of the supraclavicular, great auricular, transverse cutaneous and lesser occipital nerves
    d. Unnamed arteries derived from the occipital, transverse cervical and suprascapular arteries.
    e. Lymph vessels which pierce the deep fascia to end in the supraclavicular nodes.
3. *Investing layer of deep cervical fascia.*

Note: ***External jugular vein*** lies deep to the platysma. It is formed by union of the posterior auricular vein with the posterior division of the retromandibular vein. It begins within the lower part of the parotid gland, crosses the sternocleidomastoid obliquely, pierces the anteroinferior angle of the roof of the posterior triangle, and opens into the subclavian vein.

Its tributaries are:

a. The posterior external jugular vein
b. The transverse cervical vein
c. The suprascapular vein
d. The anterior jugular vein.

The ***oblique jugular vein*** connects the external jugular vein with the internal jugular vein across the middle one-third of the anterior border of the sternocleidomastoid.

Floor

The floor of the posterior triangle is formed by the prevertebral layer of deep cervical fascia, covering the following muscles from above downwards (Plate 3.3, Fig. 3.14):

1. Splenius capitis
2. Levator scapulae
3. Scalenus medius (Fig. 3.9b).

Division of the Posterior Triangle

It is subdivided by the inferior belly of omohyoid into:

1. A larger upper part is called the ***occipital part.***
2. A smaller lower part is called the ***supraclavicular part*** or *subclavian part* (Fig. 3.15).

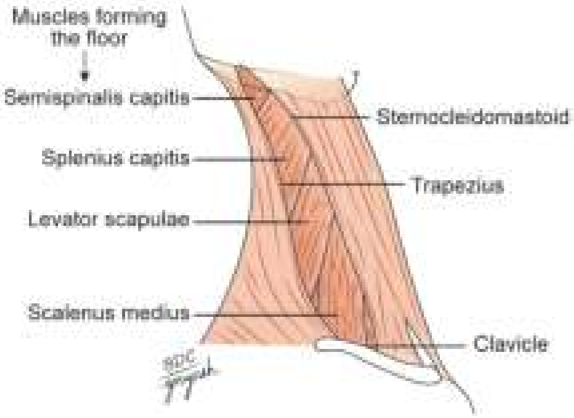

Muscles forming the floor
Semispinalis capitis
Splenius capitis
Levator scapulae
Scalenus medius
Sternocleidomastoid
Trapezius
Clavicle
BDC

Fig. 3.14: Floor of the posterior triangle

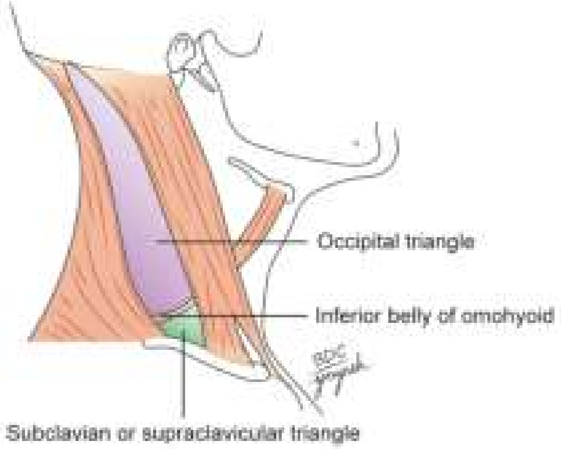

Occipital triangle
Inferior belly of omohyoid
Subclavian or supraclavicular triangle
BDC

Fig. 3.15: Divisions of the posterior triangle of neck

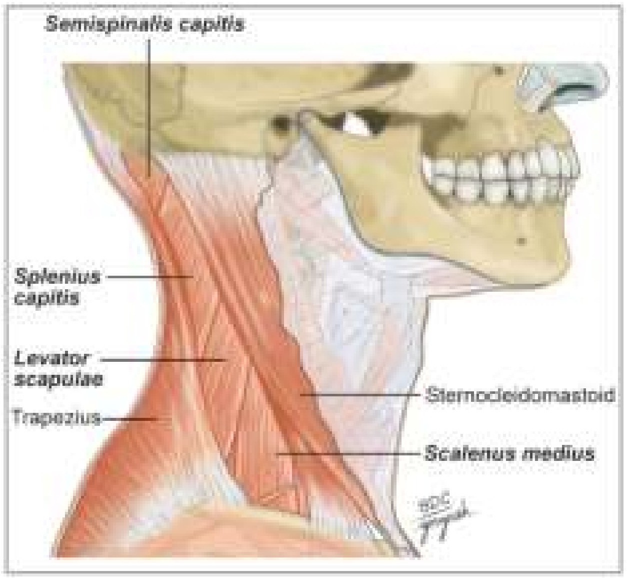
TABLE 3.1: Contents of the posterior triangle

Contents	*Occipital triangle*	*Subclavian triangle*
Nerves	Spinal accessory nerve Four cutaneous branches of cervical plexus: a. Lesser occipital (C2) b. Great auricular (C2, C3) c. Anterior cutaneous nerve of neck (C2, C3) d. Supraclavicular nerves (C3, C4) Muscular branches: a. Two small branches to the levator scapulae (C3, C4) b. Two small branches to the trapezius (C3, C4) c. Nerve to rhomboids (proprioceptive) (C5)	Roots and trunks of brachial plexus Nerve to serratus anterior (long thoracic, C5–C7) Nerve to subclavius (C5, C6) Suprascapular nerve (C5, C6)
Vessels	Transverse cervical artery and vein Occipital artery	3rd part of subclavian artery and subclavian vein Suprascapular artery and vein Commencement of transverse cervical artery and termination of the corresponding vein Lower part of external jugular vein
Lymph nodes	Along the posterior border of the sternocleidomastoid, more in the lower part—the supraclavicular nodes and a few at the upper angle—the occipital nodes	A few members of the supraclavicular chain

Note: **Details of the Contents of Posterior Triangle**

1. ***Spinal root of accessory nerve*** emerges a little above the middle of the posterior border of the sternocleidomastoid. It runs through a tunnel in the fascia forming the roof of the triangle, passing downwards and laterally and disappears under the anterior border of the trapezius about 5 cm above the clavicle. It is the only structure beneath the roof of triangle. It supplies both sternocleidomastoid and trapezius muscles.
2. The four ***cutaneous branches of the cervical plexus*** pierce the fascia covering the floor of the triangle, pass through the triangle and pierce the deep fascia at different points to become cutaneous (Plate 3.5, Fig. 3.6).
   a. ***Transverse cutaneous nerve*:** Arises from ventral rami of C2 and C3 nerves run transversely across the sternocleidomastoid to supply skin of neck, till the sternum.
   b. ***Supraclavicular nerves*:** Formed from ventral rami of C3 and C4 nerves. Emerges at posterior border of sternocleidomastoid. It descends downwards and diverges into three branches. Medial one supplies the skin over the manubrium till manubriosternal joint. Intermediate nerve crosses the clavicle to supply skin of first intercostal space to the second rib. Lateral nerve runs across the lateral side of clavicle and acromion to supply skin over the upper half of the deltoid muscle.
   c. ***Great auricular nerve*:** It is the largest ascending branch of cervical plexus. Arises from ventral rami of C2 and C3 nerves. Ascends on the sternocleidomastoid muscle to reach parotid gland, where it divides into anterior and posterior branches. Anterior branch supplies lower one-third of skin on lateral surface of pinna and skin over the parotid gland and connects the gland to the auriculotemporal nerve. This cross-connection is the anatomical basis for Frey's syndrome. Posterior branch supplies lower one-third of skin on medial surface of the pinna.
   d. ***Lesser occipital*:** Arises from ventral ramus of C2 segment of spinal cord. Seen at the posterior border of sternocleidomastoid muscle. It then winds around and ascends along its posterior border to supply skin of upper 2/3rd of medial surface of pinna adjoining part of the scalp.
3. *Muscular branches to the levator scapulae and the trapezius* (C3, C4) appear about the middle of the sternocleidomastoid. Those to the levator scapulae soon end in it; those to the trapezius run below and parallel to the accessory nerve across the middle of the triangle. Both nerves lie deep to the fascia of the floor.
4. Three ***trunks of the brachial plexus*** emerge between the scalenus anterior and medius and carry the axillary sheath around them (Fig. 3.17). The sheath contains the brachial plexus and the subclavian artery. These structures *lie deep* to *the floor* of posterior triangle. If prevertebral *fascia is left intact, all these structures are safe*.
5. The *nerve to the rhomboid* or ***dorsal scapular nerve*** is from C5 root, pierces the scalenus medius and passes deep to the levator scapulae to reach the back where it lies deep or anterior to the rhomboid muscles.
6. The ***nerve to the serratus anterior*** (C5–C7) arises by three roots. The roots from C5 and C6 pierce the scalenus medius and join the root from C7 over the first digitation of the serratus anterior. The nerve passes behind the brachial plexus. It descends over the serratus anterior in the medial wall of the axilla and gives branches to the digitations of the muscle.
7. The ***nerve to the subclavius*** (C5, C6) descends in front of the brachial plexus and the subclavian vessels, but behind the omohyoid, the transverse cervical and suprascapular vessels and the clavicle to reach the deep surface of the subclavius muscle. As it runs near the lateral margin of the scalenus anterior, it sometimes gives off the *accessory phrenic nerve* which joins the phrenic nerve in front of the scalenus anterior.
8. The ***suprascapular nerve*** (C5, C6) arises from the upper trunk of the brachial plexus and crosses the lower part of the posterior triangle just above and lateral to the brachial plexus, deep to the transverse cervical vessels and the omohyoid. It passes backwards over the shoulder to reach the scapula. It supplies the supraspinatus and infraspinatus muscles.
9. The ***subclavian artery*** passes behind the tendon of the scalenus anterior, over the first rib.
10. The ***transverse cervical artery*** is a branch of the thyrocervical trunk. It crosses the scalenus anterior, the phrenic nerve, the upper trunks of the brachial plexus, the nerve to the subclavius, the suprascapular nerve and the scalenus medius. At the anterior border of the levator scapulae, it divides into superficial and deep branches. The inferior belly of the omohyoid crosses the artery.
11. The ***suprascapular artery*** is also a branch of the thyrocervical trunk. It passes laterally and backwards behind the clavicle.
12. The ***occipital artery*** crosses the apex of the posterior triangle superficial to the splenius capitis.
13. The subclavian vein passes in front of the tendon of scalenus anterior muscle.

Plate 3.3: Muscles forming the floor of the posterior triangle



CLINICAL ANATOMY

- ***Jugular venous pressure (JVP):*** The right external jugular vein is *examined to assess the venous pressure;* the right atrial pressure is reflected in it because there are no valves in the entire course of this vein and it is straight.
- As external jugular vein pierces the deep fascia, the margins of the vein get adherent to the fascia. So if the vein gets cut, it cannot close and air is sucked in due to negative intrathoracic pressure. That causes air embolism. To prevent this, the deep fascia has to be cut (Fig. 3.6).

Competency:

AN29.5 Describe and demonstrate attachments of: (1) inferior belly of omohyoid, (2) scalenus anterior (*see* Chapter 9), (3) scalenus medius (*see* Chapter 9), and (4) levator scapulae (*see* Chapter 10).

Contents of the Posterior Triangle

(Plate 3.4, Figs 3.16a and b)

Contents of Occipital Triangle

1. Nerves:
    - Spinal accessory nerve
    - 4 cutaneous nerves: Great auricular, transverse cervical, supraclavicular and lesser occipital nerves
    - Dorsal scapular nerve for rhomboids (C5)
    - Branches from C3 and C4 root to levator scapulae and trapezius
2. Vessels:
    - Transverse cervical artery and vein
    - Occipital artery
3. Occipital nodes.

Contents of Subclavian or Supraclavicular Triangle

(Plate 3.5)

1. Nerve:
    - Root and trunk of brachial plexus
    - Nerve to serratus anterior
    - Nerve to subclavius
    - Suprascapular nerve
2. Vessels
    - 3rd part of subclavian artery
    - Subclavian vein
    - Suprascapular artery and vein
    - Transverse cervical artery and vein
    - Lower part of external jugular vein
3. Supraclavicular nodes.

These are enumerated in Table 3.1.

CLINICAL ANATOMY

- ***Supraclavicular lymphadenopathy*:** The most common swelling in the posterior triangle is due to enlargement of the supraclavicular lymph nodes. While doing biopsy of the lymph node, one must be careful in preserving the accessory nerve which may get entangled amongst enlarged lymph nodes (Fig. 3.9b).
- Supraclavicular lymph nodes are commonly enlarged in tuberculosis, Hodgkin's disease and in malignant growths of the breast, arm or chest.
- Left supraclavicular lymph nodes are also called ***Virchow's lymph nodes***. They are commonly involved in metastasis from tumours of stomach, testes and other abdominal viscera. Biopsy of supraclavicular nodes may reveal the cause of their enlargement.
- ***Block dissection of the neck*** for malignant diseases is the removal of cervical lymph nodes along with other structures involved in the growth. This procedure does not endanger those nerves of the posterior triangle which lie deep to the prevertebral fascia, i.e. the brachial and cervical plexuses and their muscular branches.
- A ***cervical rib*** may compress the 2nd part of subclavian artery. In these cases, blood supply to upper limb reaches via anastomoses around the scapula.
- Dysphagia caused by compression of the oesophagus by an abnormal subclavian artery is called ***dysphagia lusoria***.
- Elective arterial surgery of the common carotid artery is done for aneurysms, AV fistulae or arteriosclerotic occlusions. It is better to expose the common carotid artery in its upper part where it is superficial. While ligating the artery, care should be taken not to include the vagus nerve or the sympathetic chain.
- Second part of the subclavian artery may get pressed by the short scalenus anterior muscle, resulting in decreased blood supply to the upper limb. If the muscle is divided, the effects are abolished (Fig. 3.12).
- Brachial plexus block: The brachial plexus can be blocked by injecting local anaesthetic between the first rib and the skin above the clavicle. It may be required for upper limb surgeries (Fig. 3.18).

Plate 3.4: Contents of the right posterior triangle of the neck

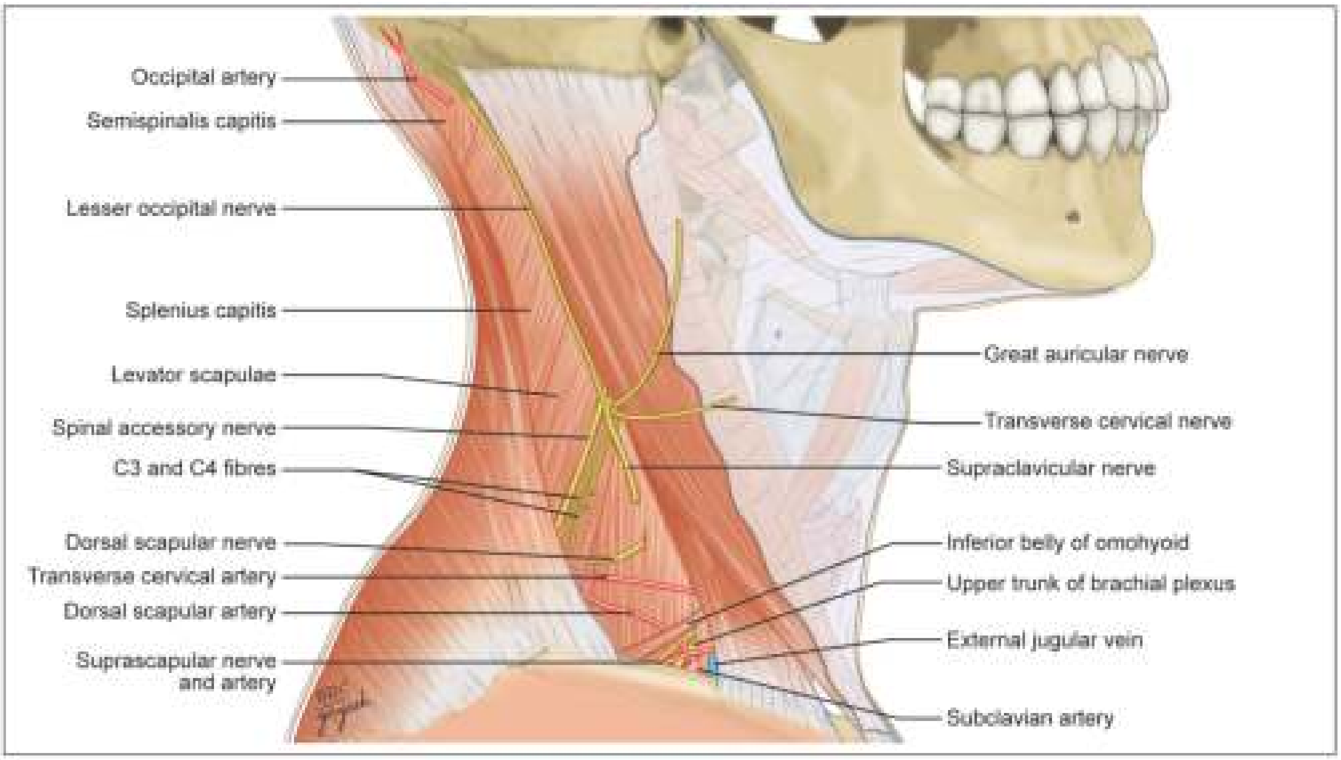
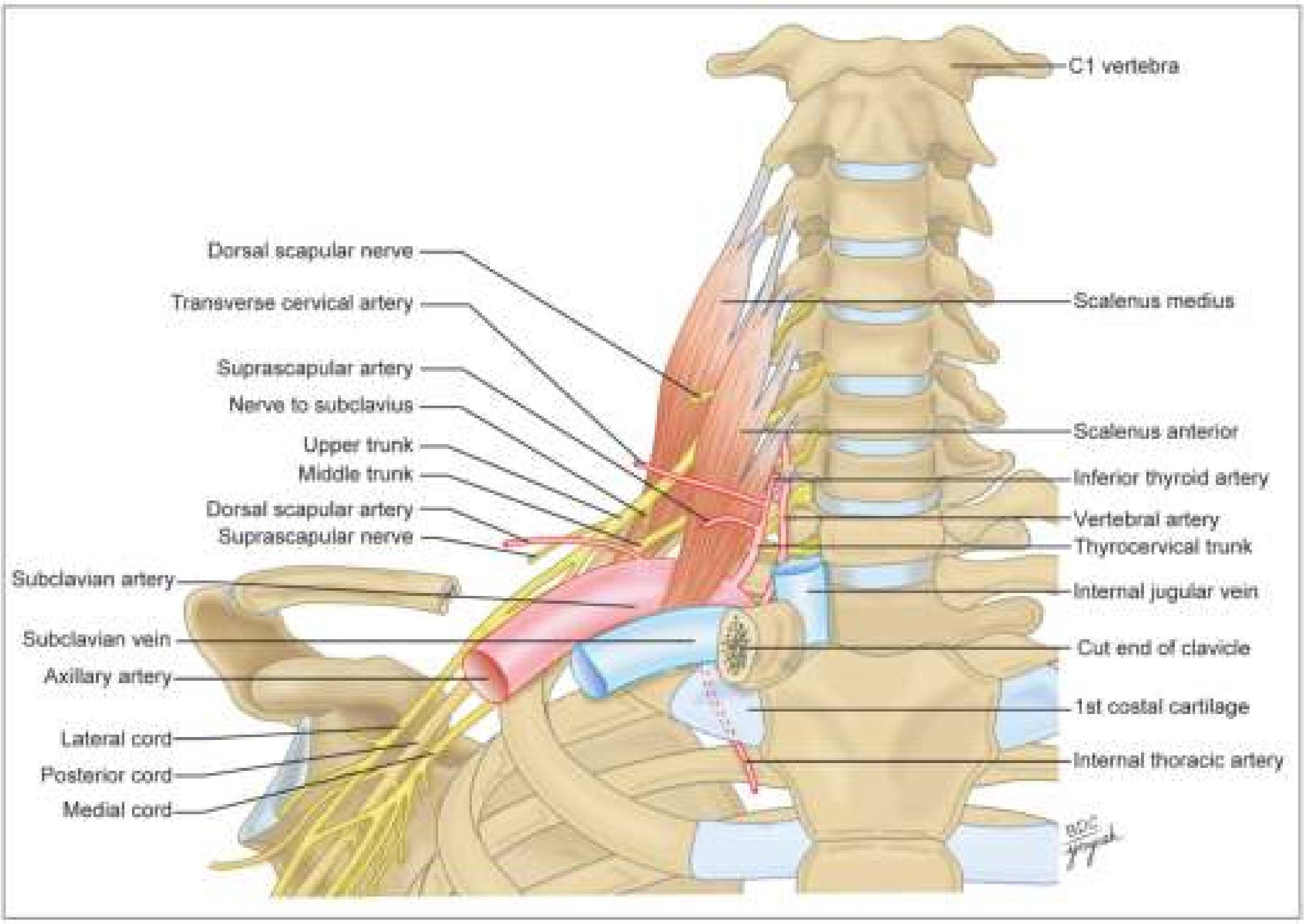
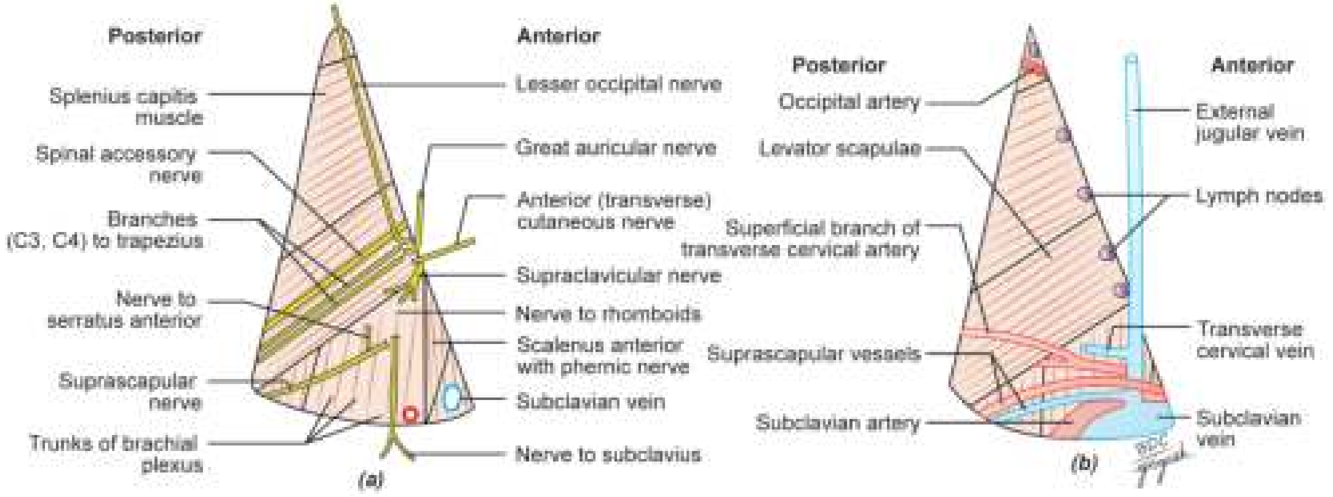

Occipital artery
Semispinalis capitis
Lesser occipital nerve
Splenius capitis
Levator scapulae
Spinal accessory nerve
C3 and C4 fibres
Dorsal scapular nerve
Transverse cervical artery
Dorsal scapular artery
Suprascapular nerve and artery
Great auricular nerve
Transverse cervical nerve
Supraclavicular nerve
Inferior belly of omohyoid
Upper trunk of brachial plexus
External jugular vein
Subclavian artery

Plate 3.5: Structures in the supraclavicular triangle of neck


C1 vertebra
Dorsal scapular nerve
Transverse cervical artery
Suprascapular artery
Nerve to subclavius
Upper trunk
Middle trunk
Dorsal scapular artery
Suprascapular nerve
Subclavian artery
Subclavian vein
Axillary artery
Lateral cord
Posterior cord
Medial cord
Scalenus medius
Scalenus anterior
Inferior thyroid artery
Vertebral artery
Thyrocervical trunk
Internal jugular vein
Cut end of clavicle
1st costal cartilage
Internal thoracic artery


Posterior
Anterior
Splenius capitis muscle
Lesser occipital nerve
Spinal accessory nerve
Great auricular nerve
Branches (C3, C4) to trapezius
Anterior (transverse) cutaneous nerve
Supraclavicular nerve
Nerve to serratus anterior
Nerve to rhomboids
Scalenus anterior with phrenic nerve
Suprascapular nerve
Subclavian vein
Trunks of brachial plexus
Nerve to subclavius
(a)
Posterior
Anterior
Occipital artery
External jugular vein
Levator scapulae
Lymph nodes
Superficial branch of transverse cervical artery
Transverse cervical vein
Suprascapular vessels
Subclavian artery
Subclavian vein
(b)

Figs 3.16a and b: The contents of posterior triangle of neck: (a) Nerves and (b) vessels and lymph nodes

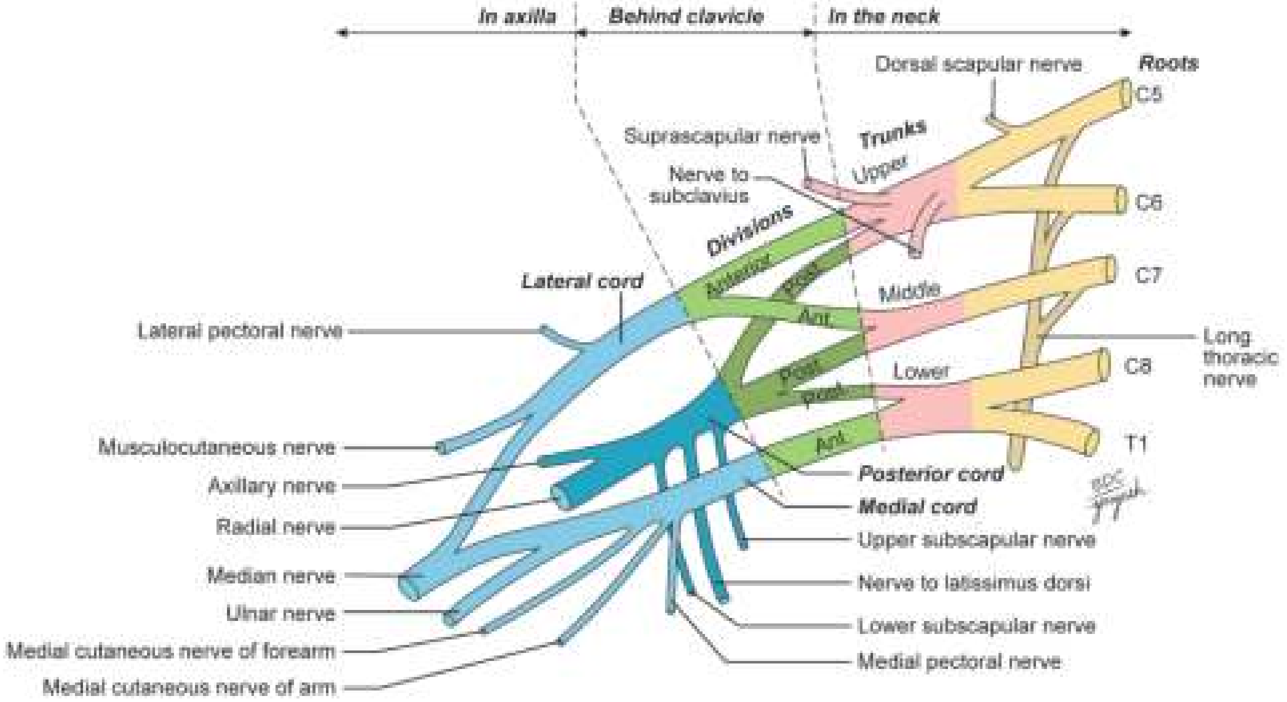

In axilla
Behind clavicle
In the neck
Dorsal scapular nerve
Roots
C5
Suprascapular nerve
Trunks
Nerve to subclavius
Upper
C6
Divisions
Lateral cord
Anterior
Post
Middle
C7
Lateral pectoral nerve
Ant
Long thoracic nerve
Post
Lower
C8
Musculocutaneous nerve
Post
Ant
T1
Axillary nerve
Posterior cord
Medial cord
Radial nerve
Upper subscapular nerve
Median nerve
Nerve to latissimus dorsi
Ulnar nerve
Lower subscapular nerve
Medial cutaneous nerve of forearm
Medial pectoral nerve
Medial cutaneous nerve of arm

Fig. 3.17: Brachial plexus

DISSECTION

Try to dissect and clean the cutaneous nerves (Fig. 3.13) which pierce the investing layer of fascia at the middle of posterior border of sternocleidomastoid muscle. Demarcate the course of external jugular vein. Cut carefully the deep fascia of posterior border of sternocleidomastoid muscle and reflect it towards trapezius muscle. Identify the accessory nerve lying just deep to the investing layer seen at the middle of the posterior border of sternocleidomastoid muscle and across the posterior triangle to reach the anterior border of trapezius which it supplies (Fig. 3.16).

Define the boundaries, roof, floor, divisions and contents of the posterior triangle (Fig. 3.16).

Identify and clean the inferior belly of omohyoid. Find the transverse cervical artery along the upper border of this muscle. Trace it both ways. Deep to this muscle is the upper or supraclavicular part of brachial plexus. Identify the roots, trunks and their branches carefully. The branches are suprascapular nerve, dorsal scapular nerve, long thoracic nerve, nerve to subclavius (Fig. 3.16). Medial to the brachial plexus locate the third part of subclavian artery.

Follow the terminal part of external jugular vein through the deep fascia into the deeply placed subclavian vein (Fig. 3.13). Identify suprascapular artery running just above the clavicle (Fig. 3.16).

Define the attachments and relations of sternocleidomastoid muscle. To expose scalenus anterior muscle, cut

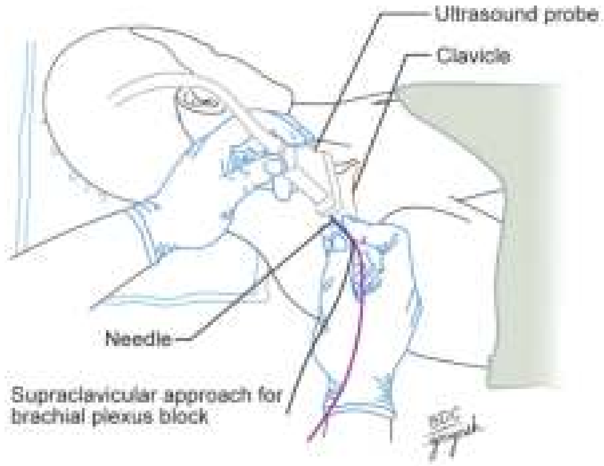


Fig. 3.18: Brachial plexus block

across the clavicular head of sternocleidomastoid muscle and push it medially. Scalenus anterior muscle covered by well-defined prevertebral fascia can be identified. Clean the subclavian artery and upper part of brachial plexus deep to the scalenus anterior muscle.

Video 3.3 Side of the Neck: Posterior triangle

Facts to Remember

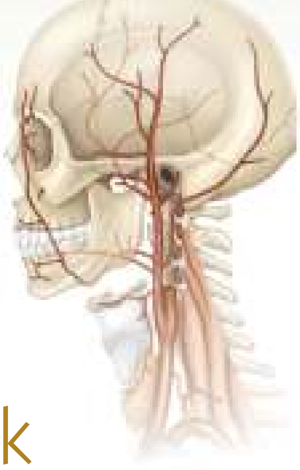
- Investing layer of deep cervical fascia encloses two muscles, two salivary glands; forms two pulleys; encloses two spaces and forms roof of posterior and anterior triangles of neck.
- Prevertebral fascia forms the axillary sheath.
- Pretracheal fascia suspends the thyroid gland.
- Ligament of Berry connects the thyroid capsule to the cricoid cartilage.
- Cold abscess of caries spine, can track down to the posterior triangle or axilla.
- Right external jugular vein is commonly used for central venous cannulation.
- Left supraclavicular nodes are called Virchow's nodes.
- Sternocleidomastoid divides the side of neck into anterior and posterior triangles.

BDC's Anatomy e-book

1. Platysma
2. External jugular vein (EJV)
3. Superficial lymph node of the neck
4. Further reading
5. Viva voce questions

Chapter

4



Anterior Region of the Neck

The anterior triangle of the neck lies between midline of the neck and sternocleidomastoid muscle. It is subdivided into smaller triangles.

SURFACE LANDMARKS

1. ***Mandible*** forms the lower jaw (Fig. 4.1). The lower border of its horseshoe-shaped body is known as the *base of the mandible*. Anteriorly, this base forms the *chin*, and posteriorly it can be traced to the *angle of the mandible*.
2. The body of the U-shaped ***hyoid bone*** can be felt in the median plane just below and behind the chin, at the junction of the neck with the floor of the mouth.
3. ***Thyroid cartilage*** of the larynx forms a sharp protuberance in the median plane just below the hyoid bone. This protuberance is called the *laryngeal prominence or* ***Adam's apple***. It is prominent in males.
4. The rounded arch of the *cricoid cartilage* lies below the thyroid cartilage at the upper end of the trachea.
5. The trachea runs downwards and backwards from the cricoid cartilage. It is identified by its cartilaginous rings. However, it is partially masked by the *isthmus of the thyroid gland*, which lies against 2nd to 4th tracheal rings. The trachea is commonly palpated in the ***suprasternal notch***, which lies between the tendinous heads of origin of the right and left sternocleidomastoid muscles.

STRUCTURES IN THE ANTERIOR MEDIAN REGION OF THE NECK

This region includes a strip 2 to 3 cm wide extending from the chin to the sternum. The structures encountered are listed below from superficial to deep (Fig. 4.2).

1. **Skin:** It is freely movable over the deeper structures due to the looseness of the superficial fascia.
2. **Superficial fascia:** It contains:
   a. Platysma
   b. Anterior jugular veins
   c. Jugular venous arch
   d. Submental lymph nodes — lying on the deep fascia below the chin
   e. Transverse or anterior cutaneous nerve of the neck.
3. **Deep fascia** (investing layer): In the upper part, it splits and encloses submandibular gland. In the lower part, it splits to enclose suprasternal space.

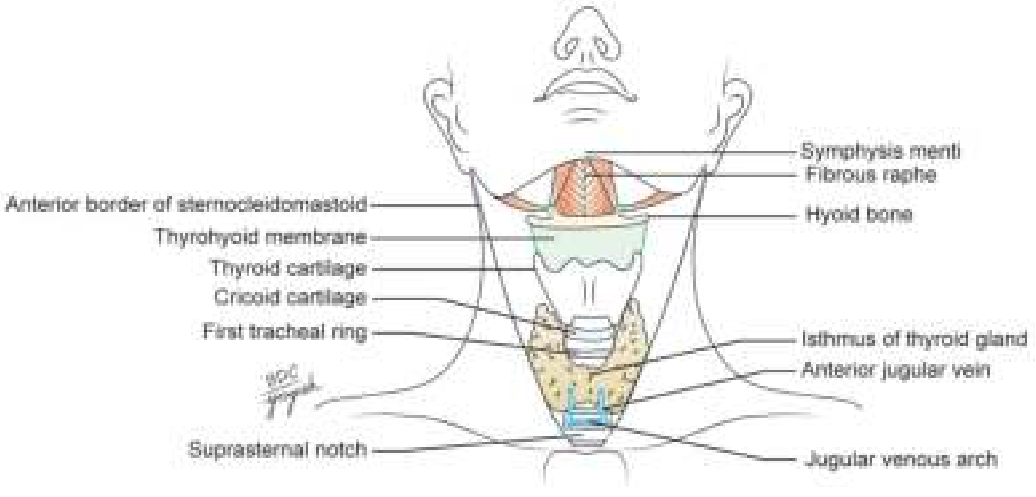

Symphysis menti
Fibrous raphe
Anterior border of sternocleidomastoid
Hyoid bone
Thyrohyoid membrane
Thyroid cartilage
Cricoid cartilage
First tracheal ring
Isthmus of thyroid gland
Anterior jugular vein
Suprasternal notch
Jugular venous arch

Fig. 4.1: Structures in the anterior median line of the neck

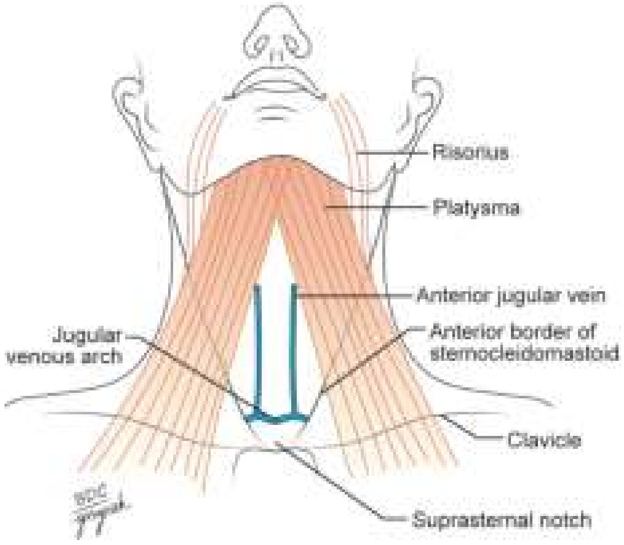


Fig. 4.2: Anterior region of the neck showing the platysma and the anterior jugular veins in the superficial fascia

4. **Deep structures lying above the hyoid bone**
   a. Mylohyoid muscle
   b. Anterior belly of digastric
   c. Superficial part of the submandibular salivary gland
   d. Mylohyoid nerve
   e. Submental branch of the facial artery
5. **Structures lying below the hyoid bone**
   These structures may be grouped into three planes:
   A. Superficial plane containing the infrahyoid muscles: Sternohyoid, sternothyroid, thyrohyoid and superior belly of omohyoid (Plate 4.1, Fig. 4.3 and Table 4.1).
   B. Middle plane consisting of the pretracheal fascia and the thyroid gland.
   C. Deep plane containing:
      a. Thyrohyoid membrane – pierced by the internal laryngeal nerve and the superior laryngeal vessels.

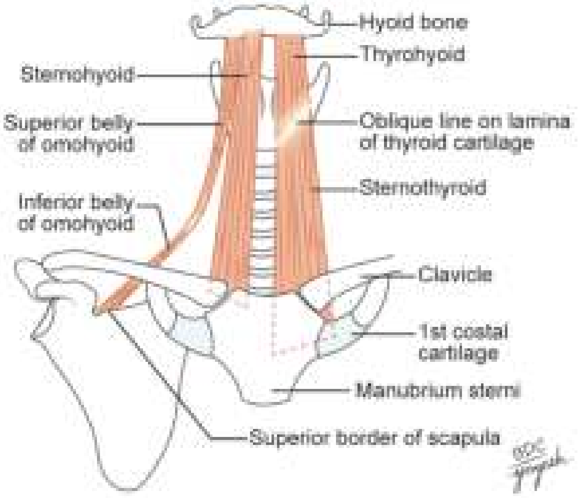

Hyoid bone
Thyrohyoid
Sternohyoid
Superior belly of omohyoid
Oblique line on lamina of thyroid cartilage
Sternothyroid
Inferior belly of omohyoid
Clavicle
1st costal cartilage
Manubrium sterni
Superior border of scapula

Fig. 4.3: The infrahyoid muscles

      b. Thyroid cartilage
      c. Cricothyroid membrane
      d. Arch of the cricoid cartilage
      e. Cricothyroid muscle
      f. Trachea, partly covered by the isthmus of the thyroid gland from the 2nd to 4th rings
      g. Carotid sheaths.

Note:
- ***Anterior jugular veins*** begin in the submental region below the chin. It descends in the superficial fascia about 1 cm from the median plane. About 2.5 cm above the sternum, it pierces the investing layer of deep fascia to enter the suprasternal space where it is connected to its fellow on the opposite side by a transverse channel, the *jugular venous arch* (Fig. 4.2). The vein then turns laterally, runs deep to the sternocleidomastoid just above the clavicle, and *ends in the external jugular vein* at the posterior border of the sternocleidomastoid.
- The anteroinferior part of the *hyoglossus muscle* is related to:
  a. The intermediate tendon of the *digastric* muscle with its fibrous pulley.
  b. The bifurcated tendon of the *stylohyoid* muscle embracing the digastric tendon (Fig. 4.3).
- The ***subhyoid bursa*** lies between the posterior surface of the body of the hyoid bone and the thyrohyoid membrane. It lessens friction between these two structures during the movements of swallowing.
- *Pretracheal fascia* forms the *false capsule of the thyroid gland* and the *suspensory ligaments of Berry* which attach the thyroid gland to the cricoid cartilage.

CLINICAL ANATOMY

- The common anterior ***midline swellings*** of the neck are:
  a. Enlarged submental lymph nodes and sublingual dermoid in the submental region.
  b. Thyroglossal cyst and inflamed subhyoid bursa just below the hyoid bone.
  c. Goitre, carcinoma of larynx and enlarged lymph nodes in the suprasternal region.
- ***Tracheostomy*** is an operation in which the trachea is opened and a tube inserted into it to facilitate breathing (Fig. 4.4).
- Cut throat wounds are most commonly situated just above or just below the hyoid bone. The main vessels of the neck usually escape injury because they are pushed backwards to a deeper plane during voluntary extension of the neck.
- ***Ludwig's angina*** is the cellulitis of the floor of the mouth. The infection spreads above the mylohyoid forcing the tongue upwards. Mylohyoid is pushed downwards. There is swelling within the mouth as well as below the chin.

DISSECTION

The skin over the anterior triangle has already been reflected following dissection in Chapter 3. Platysma is also reflected upwards. Identify the structures present in the superficial fascia and structures present in the anterior median region of neck.

Plate 4.1: Infrahyoid muscles

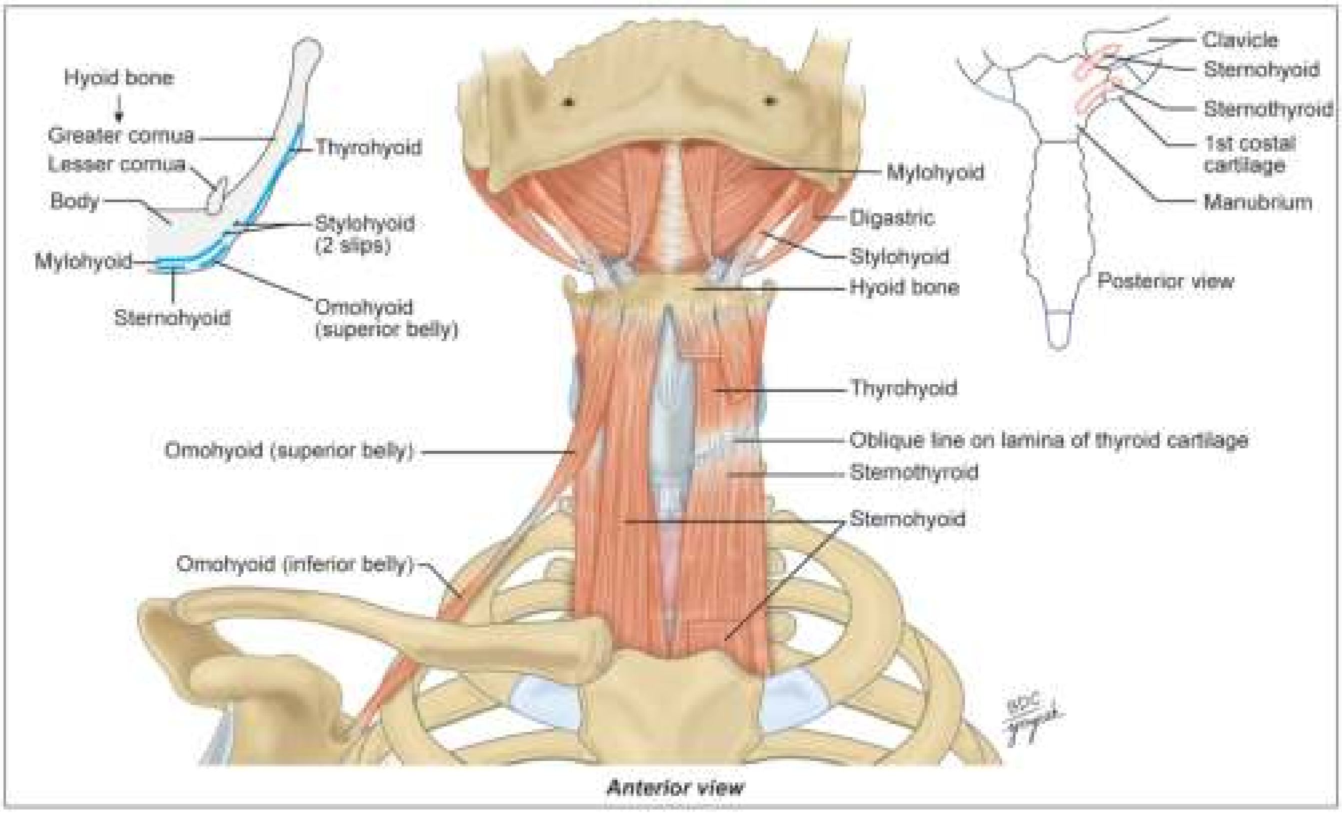

Hyoid bone
Greater cornua
Lesser cornua
Body
Mylohyoid
Sternohyoid
Thyrohyoid
Stylohyoid (2 slips)
Omohyoid (superior belly)
Mylohyoid
Digastric
Stylohyoid
Hyoid bone
Clavicle
Sternohyoid
Sternothyroid
1st costal cartilage
Manubrium
Posterior view
Thyrohyoid
Omohyoid (superior belly)
Oblique line on lamina of thyroid cartilage
Sternothyroid
Sternohyoid
Omohyoid (inferior belly)
Anterior view

TABLE 4.1: Infrahyoid muscles

Muscle	*Proximal attachment*	*Distal attachment*	*Nerve supply*	*Actions*
1. **Sternohyoid**	a. Posterior surface of manubrium sterni b. Adjoining parts of the clavicle and the posterior sternoclavicular ligament	Lower border of body of hyoid bone	Ansa cervicalis (C1–C3)	Depresses the hyoid bone following its elevation during swallowing and during vocal movements
2. **Sternothyroid:** It lies deep to the sternohyoid	a. Posterior surface of manubrium sterni b. Adjoining part of 1st costal cartilage	Oblique line on the lamina of the thyroid cartilage	Ansa cervicalis (C1–C3)	Depresses the larynx after it has been elevated in swallowing and in vocal movements
3. **Thyrohyoid:** It lies deep to the sternohyoid	Oblique line of thyroid cartilage	Lower border of the body and the greater cornua of the hyoid bone	C1 through hypoglossal nerve	a. Depresses the hyoid bone b. Elevates the larynx when the hyoid is fixed by the suprahyoid muscles
4. **Omohyoid:** It has an inferior belly, a common tendon and a superior belly. It arises by the inferior belly, and is inserted through the superior belly	a. Upper border of scapula near the suprascapular notch b. Adjoining part of suprascapular ligament	Lower border of body of hyoid bone lateral to the sternohyoid. The central tendon lies on the internal jugular vein at the level of the cricoid cartilage and is bound to the clavicle by a fascial pulley	Superior belly by the superior root of the ansa cervicalis, and inferior belly by inferior root of ansa cervicalis	Depresses the hyoid bone following its elevation during swallowing or in vocal movements

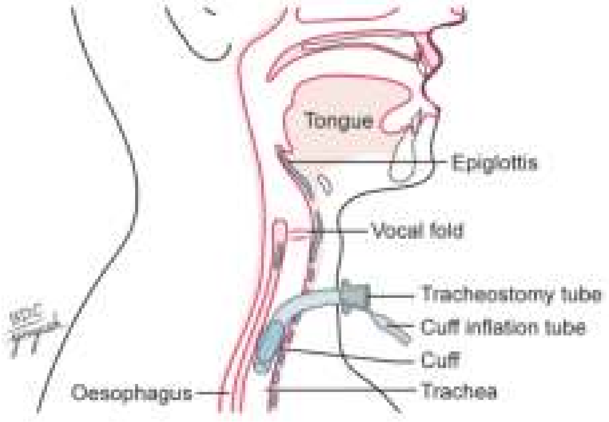

Tongue
Epiglottis
Vocal fold
Tracheostomy tube
Cuff inflation tube
Cuff
Trachea
Oesophagus

Fig. 4.4: Tracheostomy tube in position

Competency:
AN32.1 Describe boundaries and subdivisions of anterior triangle.

ANTERIOR TRIANGLE

The anterior triangle of the neck is a triangular area (Plate 4.2, Fig. 4.5).

Boundaries

Anterior:	Anterior median plane of the neck
Posterior:	Anterior border of sternocleidomastoid
Base:	Base of the mandible and a line joining the angle of the mandible to the mastoid process, superiorly
Apex:	It is directed downward. It is formed by the meeting point of anterior border of sternocleidomastoid muscle and anterior median line muscle and anterior median line.

Roof:
1. Skin
2. Superficial fascia with platysma
3. Investing layer of deep cervical fascia

Subdivisions

The anterior triangle is subdivided (by the digastric muscle and the superior belly of the omohyoid) into:
1. Submental,
2. Digastric,
3. Carotid, and
4. Muscular triangles (Fig. 4.5).

Competency:
AN32.2 Describe and demonstrate boundaries and contents of digastric and submental triangles.

SUBMENTAL TRIANGLE

This is a median triangle. It is bounded as follows (Plate 4.3, Fig. 4.6, Flowchart 4.1).

Boundaries

Apex:	Lower border of symphysis menti or chin
Base:	Body of the hyoid bone
On each side:	Anterior bellies of digastric muscles
Floor:	Mylohyoid muscle and the median raphe extending from symphysis menti to the body of the hyoid bone
Roof:	Investing layer of deep cervical fascia.

Contents

1. Two to four small *submental lymph nodes*
2. Small submental veins join to form the anterior jugular veins.

Note: The ***submental lymph nodes*** are situated in the superficial fascia between the anterior bellies of the digastric muscles. They drain:
- a. Superficial tissues below the chin
- b. Central part of the lower lip
- c. The adjoining gums
- d. Anterior part of the floor of the mouth
- e. The tip of the tongue.

Their efferents pass to the submandibular nodes.

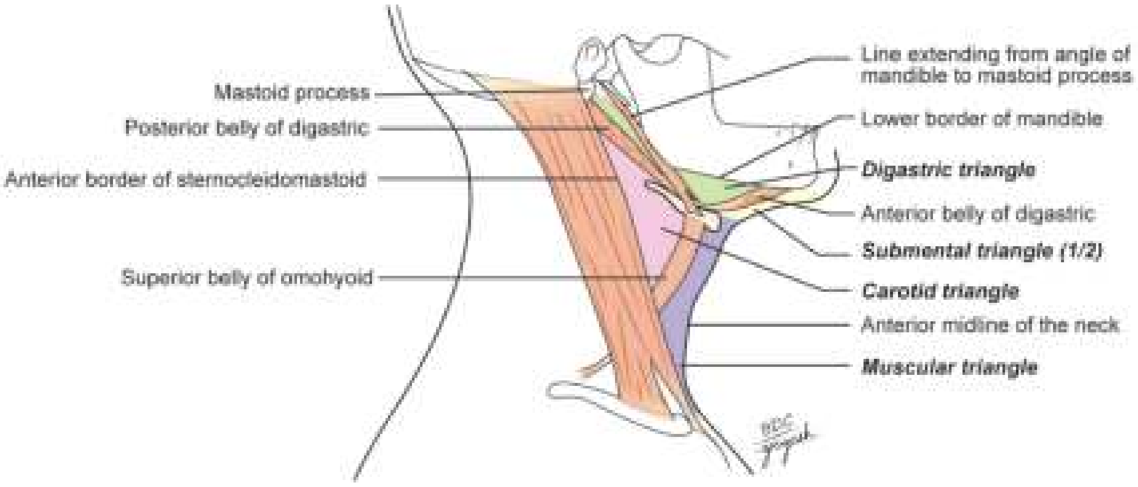

Mastoid process
Posterior belly of digastric
Anterior border of sternocleidomastoid
Superior belly of omohyoid
Line extending from angle of mandible to mastoid process
Lower border of mandible
Digastric triangle
Anterior belly of digastric
Submental triangle (1/2)
Carotid triangle
Anterior midline of the neck
Muscular triangle

Fig. 4.5: The triangles of the neck. The anterior triangle is subdivided by digastric and superior belly of omohyoid. Posterior triangle is subdivided by inferior belly of omohyoid

Plate 4.2: Boundaries and subdivisions of the anterior triangle

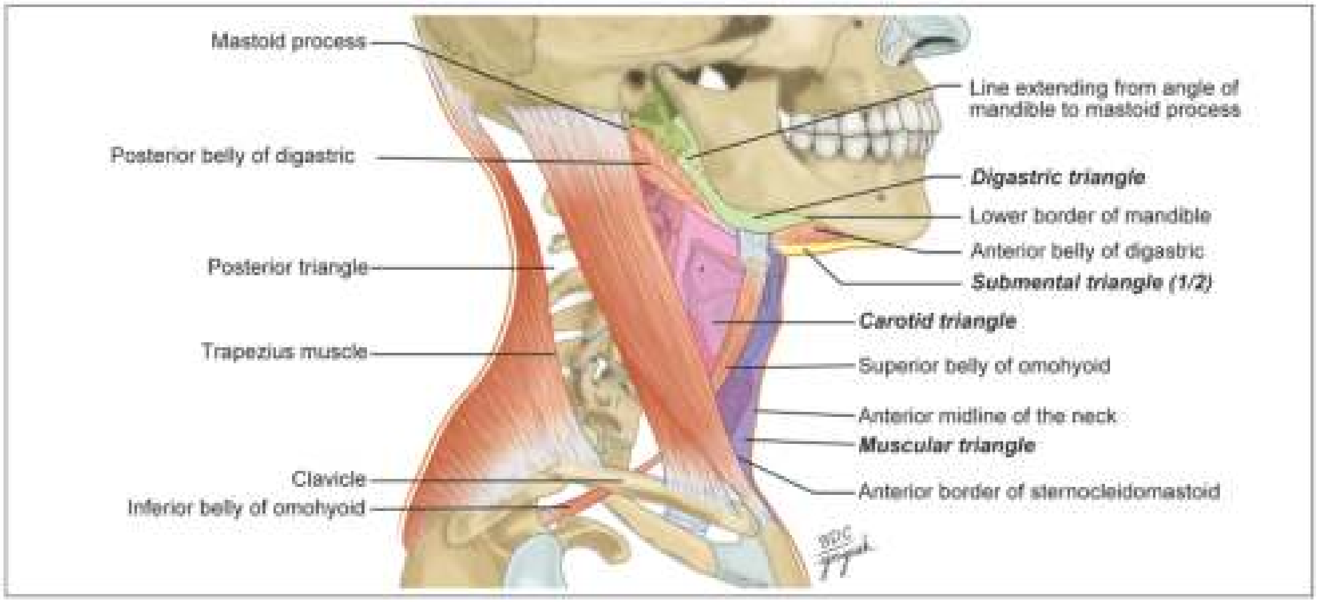
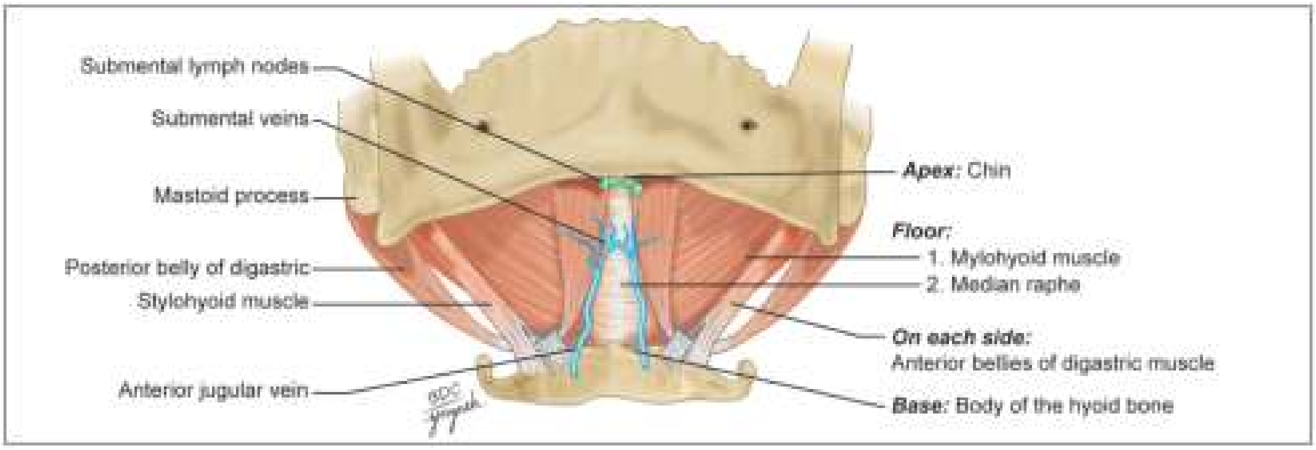

Mastoid process
Posterior belly of digastric
Posterior triangle
Trapezius muscle
Clavicle
Inferior belly of omohyoid
Line extending from angle of mandible to mastoid process
Digastric triangle
Lower border of mandible
Anterior belly of digastric
Submental triangle (1/2)
Carotid triangle
Superior belly of omohyoid
Anterior midline of the neck
Muscular triangle
Anterior border of sternocleidomastoid

Plate 4.3: Boundaries and contents of the submental triangle


Submental lymph nodes
Submental veins
Mastoid process
Posterior belly of digastric
Stylohyoid muscle
Anterior jugular vein
Apex: Chin
Floor:
1. Mylohyoid muscle
2. Median raphe
On each side:
Anterior bellies of digastric muscle
Base: Body of the hyoid bone

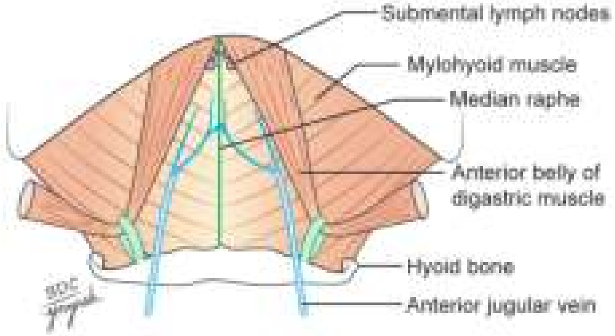
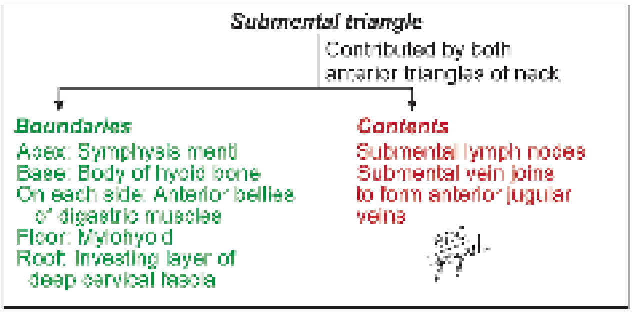

Submental lymph nodes
Mylohyoid muscle
Median raphe
Anterior belly of digastric muscle
Hyoid bone
Anterior jugular vein

Fig. 4.6: Boundaries and contents of the submental triangle

Flowchart 4.1: Submental triangle


Submental triangle
Contributed by both anterior triangles of neck
Boundaries
Apex: Symphysis menti
Base: Body of hyoid bone
On each side: Anterior bellies of digastric muscles
Floor: Mylohyoid
Roof: Investing layer of deep cervical fascia
Contents
Submental lymph nodes
Submental vein joins to form anterior jugular veins

DIGASTRIC (SUBMANDIBULAR) TRIANGLE

The digastric triangle is also called submandibular triangle as it is located below the base of mandible (Figs 4.7and 4.8 and Flowchart 4.2).

Note: The area between the body of the mandible and the hyoid bone is known as the ***submandibular region***. The superficial structures of this region lie in the submental and digastric triangles.

Boundaries

Anteroinferiorly:	Anterior belly of digastric
Posteroinferiorly:	Posterior belly of digastric and the stylohyoid
Superiorly or base:	Base of the mandible and a line joining the angle of the mandible to the mastoid process.
Apex:	Intermediate tendon of digastric muscle

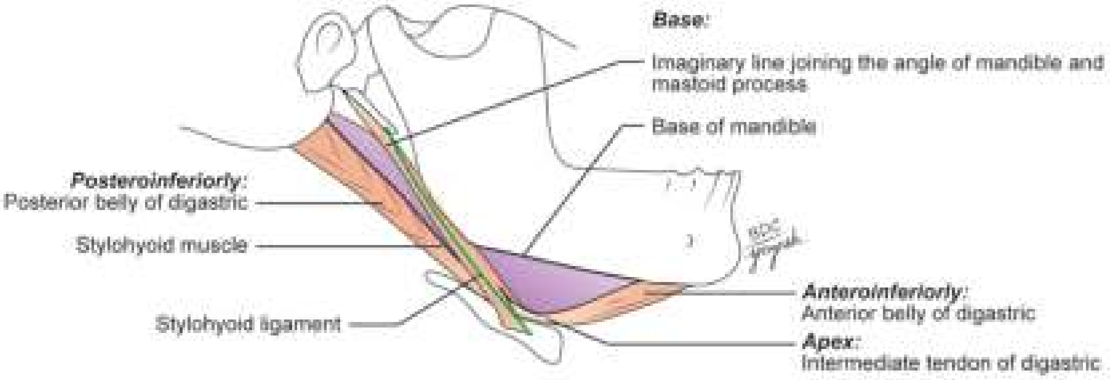

Base:
Imaginary line joining the angle of mandible and mastoid process
Base of mandible
Posteroinferiorly:
Posterior belly of digastric
Stylohyoid muscle
Stylohyoid ligament
Anteroinferiorly:
Anterior belly of digastric
Apex:
Intermediate tendon of digastric

Fig. 4.7: Boundaries of the digastric triangle

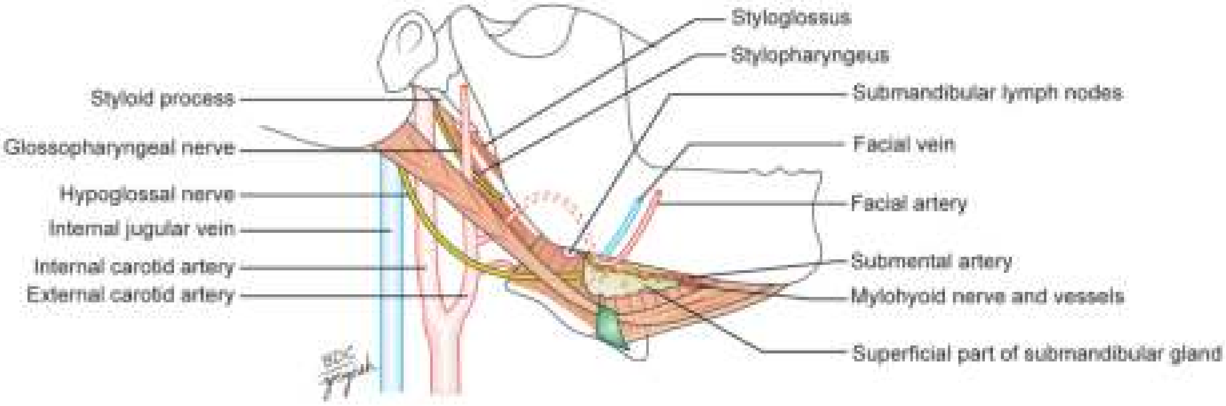
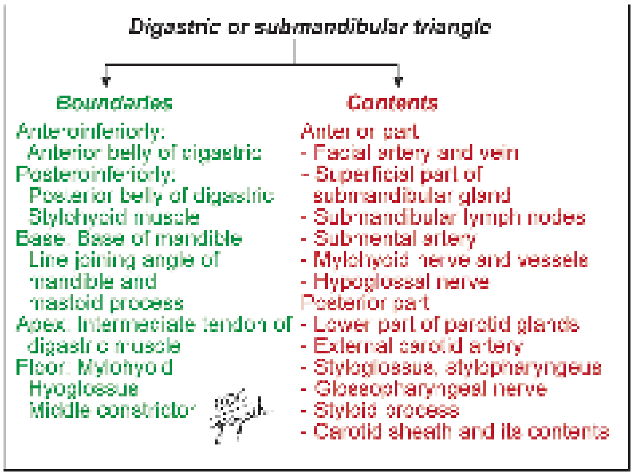

Styloglossus
Stylopharyngeus
Submandibular lymph nodes
Facial vein
Facial artery
Submental artery
Mylohyoid nerve and vessels
Superficial part of submandibular gland
Styloid process
Glossopharyngeal nerve
Hypoglossal nerve
Internal jugular vein
Internal carotid artery
External carotid artery

Fig. 4.8: Contents of the digastric triangle

Flowchart 4.2: Digastric or submandibular triangle



Digastric or submandibular triangle

Boundaries

Anteroinferiorly:
  Anterior belly of digastric
Posteroinferiorly:
  Posterior belly of digastric
  Stylohyoid muscle
Base: Base of mandible
  Line joining angle of mandible and mastoid process
Apex: Intermediate tendon of digastric muscle
Floor: Mylohyoid
  Hyoglossus
  Middle constrictor

Contents

Anterior part
- Facial artery and vein
- Superficial part of submandibular gland
- Submandibular lymph nodes
- Submental artery
- Mylohyoid nerve and vessels
- Hypoglossal nerve

Posterior part
- Lower part of parotid glands
- External carotid artery
- Styloglossus, stylopharyngeus
- Glossopharyngeal nerve
- Styloid process
- Carotid sheath and its contents

Roof: The roof of the triangle is formed by:

1. Skin
2. Superficial fascia, containing:
    a. Platysma
    b. Cervical branch of the facial nerve
    c. Ascending branch of the transverse or anterior cutaneous nerve of the neck.
3. Deep fascia, which splits to enclose the submandibular salivary gland.

Floor

1. Mylohyoid muscle
2. Hyoglossus
3. Middle constrictor muscle of the pharynx.

Contents (Fig. 4.8)

The ***stylomandibular ligament*** divides the triangle into anterior and posterior parts.

Anterior Part of the Triangle

Structures superficial to mylohyoid are:

1. Superficial part of the submandibular salivary gland
2. Facial vein
3. Submandibular lymph nodes
4. Facial artery is deep to it
5. Submental artery
6. Mylohyoid nerve and vessels
7. Hypoglossal nerve.

Posterior Part of the Triangle

1. *Superficial structures* are:
    a. Lower part of the parotid gland
    b. External carotid artery
2. *Deep structures*, passing between the external and internal carotid arteries, are:
    a. Styloglossus
    b. Stylopharyngeus
    c. Glossopharyngeal (IX) nerve
    d. Pharyngeal branch of the vagus nerve

  - e. Styloid process
  - f. A part of the parotid gland.

3. *Deepest structures* include:
  - a. Internal carotid artery
  - b. Internal jugular vein
  - c. Vagus nerve.

DISSECTION

Remove the deep fascia from anterior bellies of digastric muscles to expose parts of two mylohyoid muscles. Clean the boundaries and contents of the submental triangle.

Cut the deep fascia from the mandible and reflect it downwards to expose the submandibular gland. Identify and clean anterior and posterior bellies of digastric muscles, which form the boundaries of digastric triangle. Identify the intermediate tendon of digastric after pulling the submandibular gland laterally. Clean the stylohyoid muscle, which envelops the tendon of digastric and is lying above with the posterior belly of digastric muscle (Fig. 4.7). Identify the contents of digastric triangle.

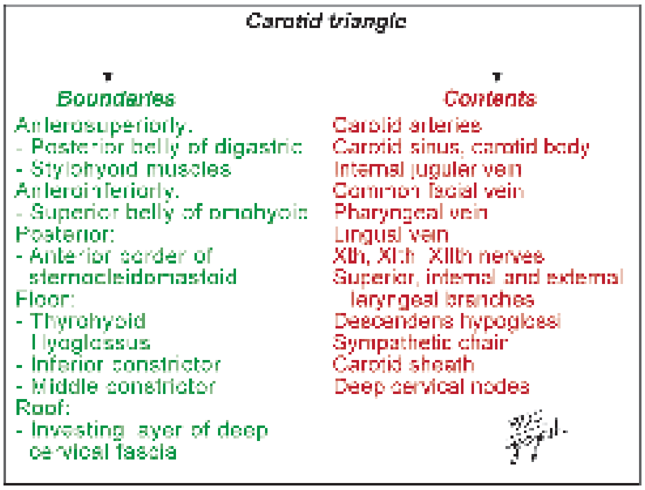
Competency:
AN32.2 Describe and demonstrate boundaries and contents of muscular, carotid triangles.

CAROTID TRIANGLE

Boundaries

Anterosuperiorly: Posterior belly of the digastric muscle; and the stylohyoid (Plate 4.4, Fig. 4.9 and Flowchart 4.3).

Flowchart 4.3: Carotid triangle


Carotid triangle
Boundaries
Anterosuperiorly:
- Posterior belly of digastric
- Stylohyoid muscles
Anteroinferiorly:
- Superior belly of omohyoid
Posterior:
- Anterior border of sternocleidomastoid
Floor:
- Thyrohyoid
Hyoglossus
- Inferior constrictor
- Middle constrictor
Roof:
- Investing layer of deep cervical fascia
Contents
Carotid arteries
Carotid sinus, carotid body
Internal jugular vein
Common facial vein
Pharyngeal vein
Lingual vein
Xth, XIth, XIIth nerves
Superior, internal and external laryngeal branches
Descendens hypoglossi
Sympathetic chain
Carotid sheath
Deep cervical nodes

Anteroinferiorly: Superior belly of the omohyoid.

Posteriorly: Anterior border of the sternocleidomastoid muscle

Roof:

1. Skin
2. Superficial fascia containing:
   - a. Platysma
   - b. Cervical branch of the facial nerve
   - c. Transverse cervical nerve of the neck.
3. Investing layer of deep cervical fascia.

Floor:

1. Middle constrictor of pharynx
2. Inferior constrictor of the pharynx
3. Thyrohyoid membrane.

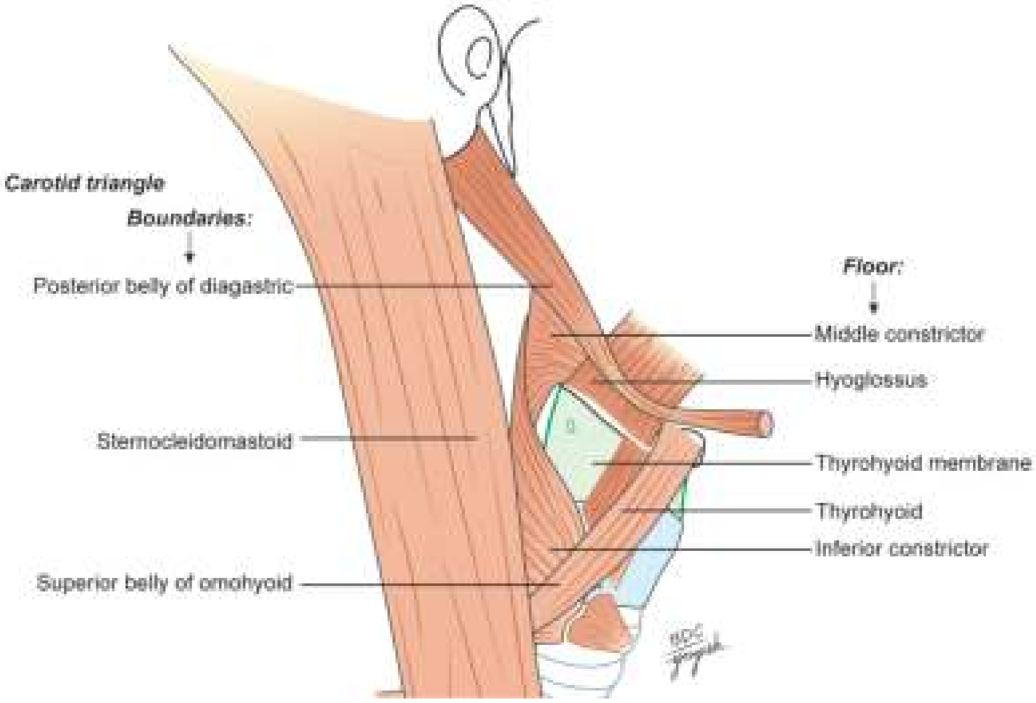
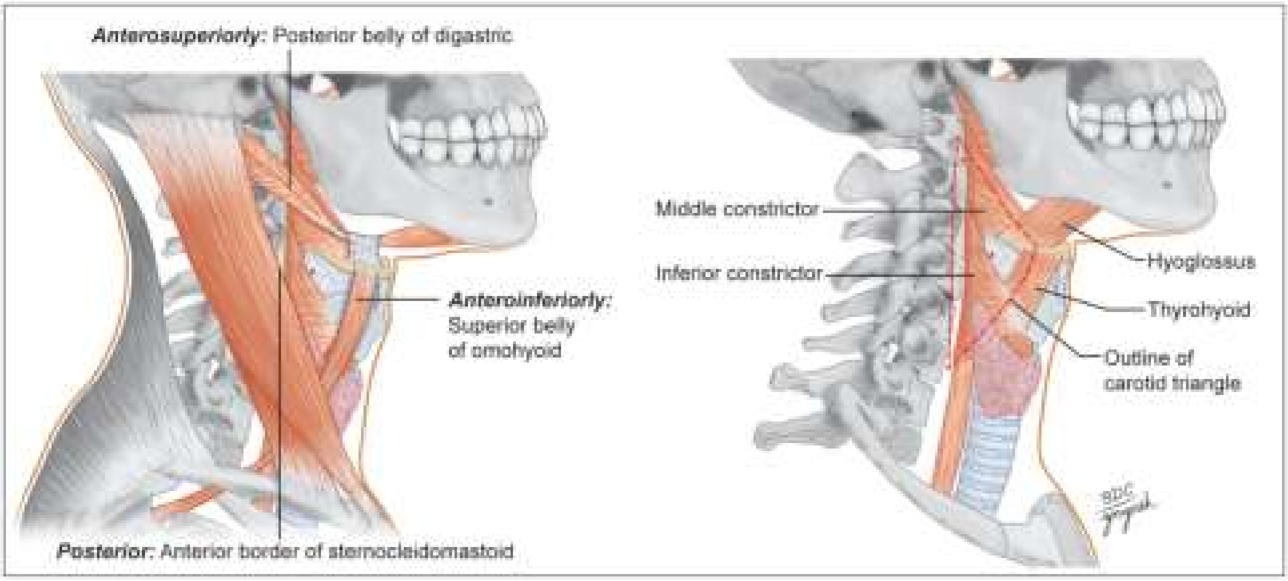

Carotid triangle
Boundaries:
Posterior belly of diagastric
Sternocleidomastoid
Superior belly of omohyoid
Floor:
Middle constrictor
Hyoglossus
Thyrohyoid membrane
Thyrohyoid
Inferior constrictor

Fig. 4.9: Boundaries and floor of the carotid triangle

Plate 4.4: Carotid triangle: Boundaries and floor


Anterosuperiorly: Posterior belly of digastric
Anteroinferiorly: Superior belly of omohyoid
Posterior: Anterior border of sternocleidomastoid
Middle constrictor
Inferior constrictor
Hyoglossus
Thyrohyoid
Outline of carotid triangle
SDC jayesh

Contents (Fig. 4.10)

Arteries

1. Carotid arteries: Common, internal, external
2. Carotid sinus and carotid body
3. Superior thyroid, lingual, facial, ascending pharyngeal and occipital arteries.

Veins

1. Internal jugular vein
2. Common facial vein draining into the internal jugular vein
3. Pharyngeal vein which usually ends in the internal jugular vein
4. Lingual vein which usually terminates in the internal jugular vein.

Nerves

1. Vagus nerve
2. Spinal accessory nerve
3. Hypoglossal nerve – gives off the superior root of the ansa cervicalis or descendens hypoglossi, and another branch to the thyrohyoid.
4. Superior laryngeal branch of the vagus, dividing into the external and internal laryngeal nerves.
5. Sympathetic chain.
6. *Carotid sheath* with its contents.

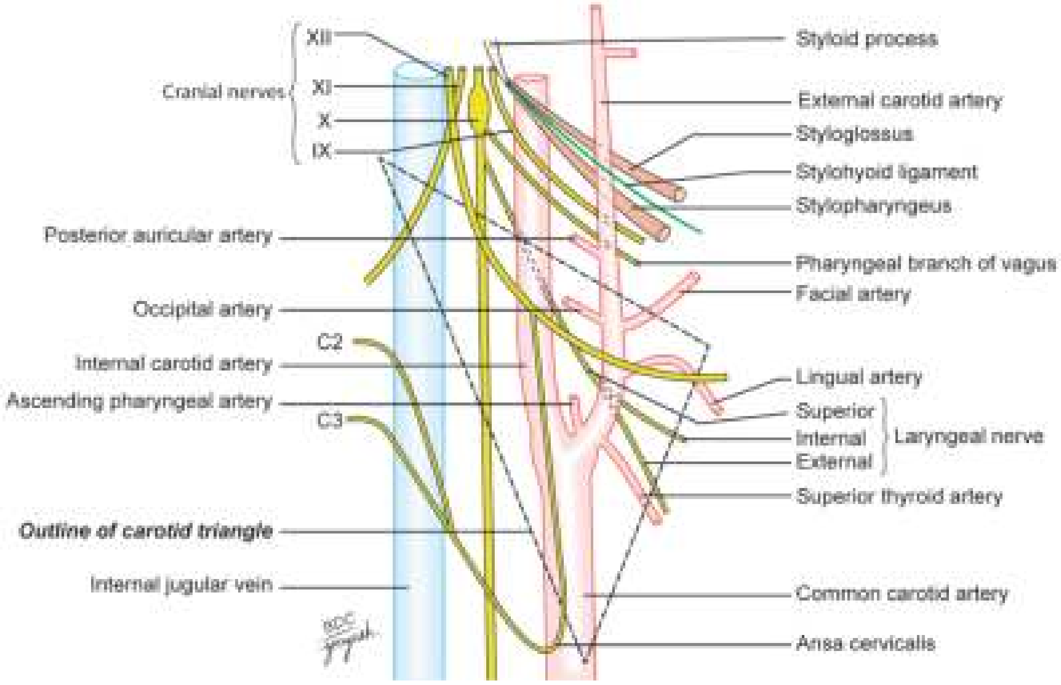

Cranial nerves
XII
XI
X
IX
Posterior auricular artery
Occipital artery
C2
Internal carotid artery
Ascending pharyngeal artery
C3
Outline of carotid triangle
Internal jugular vein
Styloid process
External carotid artery
Styloglossus
Stylohyoid ligament
Stylopharyngeus
Pharyngeal branch of vagus
Facial artery
Lingual artery
Superior
Internal
External
Laryngeal nerve
Superior thyroid artery
Common carotid artery
Ansa cervicalis
SDC jayesh

Fig. 4.10: The IXth, Xth, XIth and XIIth cranial nerves and their branches related to the carotid arteries and to the internal jugular vein, in and around the right carotid triangle

Lymph Nodes

Deep cervical lymph nodes include the jugulodigastric node below the posterior belly of the digastric and the jugulo-omohyoid node above the inferior belly of the omohyoid.

DISSECTION

Clean the area situated between posterior belly of digastric and superior belly of omohyoid muscle, to expose the carotid arteries with internal jugular vein. Trace IX, X, XI and XII nerves in relation to these vessels.

Identify middle and inferior constrictors of pharynx and thyrohyoid membrane forming its floor.

Carefully clean and preserve superior root, the loop and inferior root of ansa cervicalis in relation to anterior aspect of carotid sheath. Locate the sympathetic trunk situated posteromedial to the carotid sheath. Dissect the branches of external carotid artery. Identify and preserve the internal laryngeal nerve in the thyrohyoid interval. Trace it posterosuperiorly till vagus. Also look for external laryngeal nerve supplying the cricothyroid muscle.

The carotid triangle provides a good view of all the large vessels and nerves of the neck, particularly when its posterior boundary is retracted slightly backwards.

MUSCULAR TRIANGLE

Boundaries

Anteriorly:	Anterior median line of the neck from the hyoid bone to the sternum.
Posterosuperiorly:	Superior belly of the omohyoid muscle.
Posteroinferiorly:	Lower part of anterior border of the sternocleidomastoid muscle.
Floor:	It is formed by pretracheal fascia, thyroid and cricoid cartilages and trachea
Roof:	Investing layer of deep cervical fascia.

Contents

The infrahyoid muscles are the chief contents of the triangle. These muscles may also be regarded arbitrarily as forming the floor of the triangle (Fig. 4.11).

The *infrahyoid muscles* are:

a. Sternohyoid
b. Sternothyroid
c. Thyrohyoid
d. Omohyoid.

Note: ***Peculiarities of infrahyoid muscles***

a. Arranged in two layers – Superficial (sternohyoid and omohyoid) and deep (sternothyroid and thyrohyoid).
b. Supplied by the ventral rami of C1, C2, and C3 spinal nerves.
c. Because of their attachment to the hyoid bone and to the thyroid cartilage, they move these structures.
d. Sternohyoid, superior belly of omohyoid, and sternothyroid lie superficial to the lateral or superficial convex surface of the thyroid gland.
e. The anterior surface of isthmus of thyroid gland is covered by right and left sternothyroid and sternohyoid muscles.

The specific details of infrahyoid muscles are shown in Table 4.1.

DISSECTION

Identify the infrahyoid muscles on each side of the median plane. Cut through the origin of sternocleidomastoid muscle and reflect it upwards. Trace the nerve supply of infrahyoid muscles.

The superficial structures in the infrahyoid region are included in this triangle. The deeper structures (thyroid gland, trachea, oesophagus, etc.) will be studied separately at a later stage.

ANSA CERVICALIS OR ANSA HYPOGLOSSI

Definition: It is also called ***ansa hypoglossi***. It is a loop of nerve fibres embedded in the anterior wall of the carotid sheath (Fig. 4.12, Flowchart 4.4).

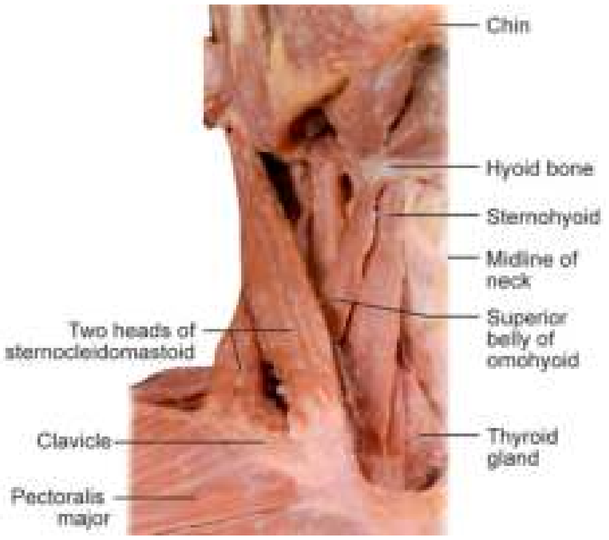

Chin
Hyoid bone
Sternohyoid
Midline of neck
Superior belly of omohyoid
Two heads of sternocleidomastoid
Thyroid gland
Clavicle
Pectoralis major

Fig. 4.11: Dissection of muscular triangle

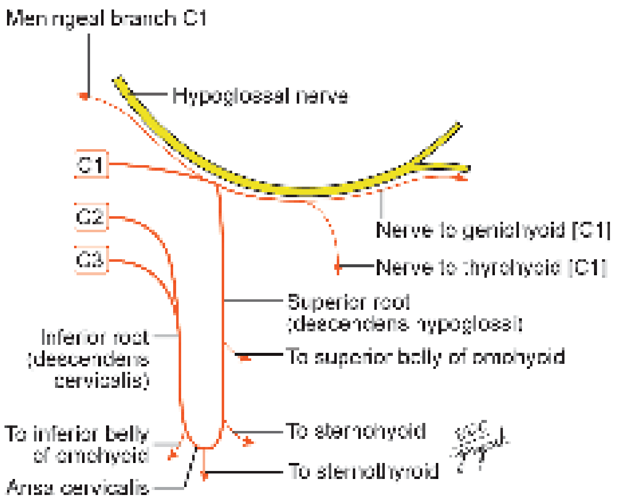
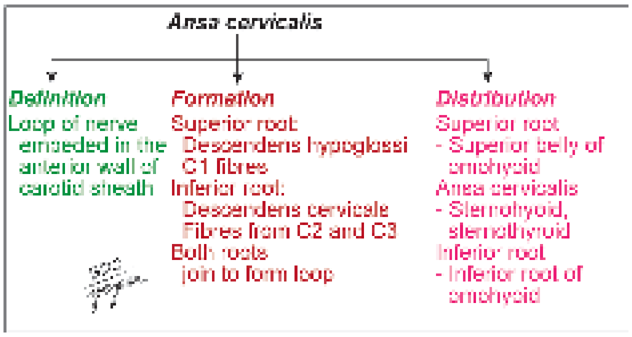

Meningeal branch C1
Hypoglossal nerve
C1
C2
C3
Nerve to geniohyoid [C1]
Nerve to thyrohyoid [C1]
Superior root (descendens hypoglossi)
Inferior root (descendens cervicalis)
To superior belly of omohyoid
To inferior belly of omohyoid
To sternohyoid
Ansa cervicalis
To sternothyroid

Fig. 4.12: Ansa cervicalis and branches of the first cervical nerve distributed through the hypoglossal nerve

Flowchart 4.4: Ansa cervicalis



Formation

It is formed by a superior and an inferior root.

1. ***Superior root** or **descendens hypoglossi*** is the continuation of the descending branch of the hypoglossal nerve. Its fibres are derived from the C1 nerve. This root descends over the internal carotid artery and the common carotid artery.
2. ***Inferior root** or **descendens cervicalis*** is derived from C2 and C3 spinal nerves. As this root descends, it winds around the internal jugular vein and then continues anteroinferiorly to join the superior root in front of the common carotid artery.

Distribution

1. *Superior root:* To the superior belly of the omohyoid.
2. *Ansa cervicalis:* To the sternohyoid, the sternothyroid.
3. *Inferior root:* To the inferior belly of the omohyoid.

Note: The thyrohyoid and geniohyoid are supplied by separate branches from the first cervical nerve through the hypoglossal nerve.

COMMON CAROTID ARTERY

The right common carotid artery is a branch of the brachiocephalic artery. It begins in the neck behind the right sternoclavicular joint. The left common carotid artery is branch of the arch of the aorta.

Carotid Sinus

The termination of the common carotid artery, or the beginning of the internal carotid artery shows a slight dilatation, known as the carotid sinus. In this region, the tunica media is thin, but the adventitia is relatively thick and receives a rich innervation from the glossopharyngeal and sympathetic nerves. The carotid sinus acts as a ***baroreceptor*** or *pressure receptor* and regulates ***blood pressure***.

Carotid Body

Carotid body is a small, oval reddish brown structure situated behind the bifurcation of the common carotid artery. It receives a rich nerve supply mainly from the glossopharyngeal nerve, but also from the vagus and sympathetic nerves. It acts as a ***chemoreceptor*** and responds to changes in the oxygen, carbon dioxide and **pH** content of the blood.

Other *allied chemoreceptors* are found near the arch of the aorta, the ductus arteriosus and the right subclavian artery. These are supplied by the vagus nerve.

CLINICAL ANATOMY

- ***Carotid tubercle***: It is a tubercle on the transverse process of ***C6*** vertebra. CCA can be compressed against the tubercle. It lies about 4 cm above the sternoclavicular joint.
- The carotid sinus is richly supplied by nerves. In some persons, the sinus may be hypersensitive. In such persons, sudden rotation of the head may cause slowing of heart. This condition is called '***carotid sinus syndrome***'.
- ***Potato tumour of neck*** is produced by enlargement of the carotid body. The tumour moves transversely. It is pulsating and produces attacks of fainting due to pressure on carotid sinus. The supraventricular tachycardia may be controlled by carotid sinus massage, due to inhibitory effects of vagus nerve on the heart.
- The necktie should not be tied tightly, as it may compress both the internal carotid arteries, supplying the brain.

EXTERNAL CAROTID ARTERY

External carotid artery is one of the terminal branches of the common carotid artery. In general, it lies anterior to the internal carotid artery and supply the structures in the front of the neck and in the face (Fig. 4.13).

Course and Relations

1. External carotid artery runs in the carotid and digastric triangles and then in the substance of parotid gland.
2. The external carotid artery begins in the carotid triangle at the level of the upper border of the thyroid cartilage opposite the disc between the 3rd and 4th cervical vertebrae. It runs upwards and slightly backwards and laterally and terminates behind the neck of the mandible by dividing into the maxillary and superficial temporal arteries.
3. The external carotid artery has a *slightly curved course* so that it is anteromedial to the internal carotid artery in its lower part and anterolateral to the internal carotid artery in its upper part.
4. *In the carotid triangle*, the external carotid artery is comparatively superficial and lies under cover of the anterior border of the sternocleidomastoid. The artery is crossed superficially by the cervical branch of the facial nerve, the hypoglossal nerve and the facial, lingual and superior thyroid veins.

   Deep to the artery, there are:
   a. Wall of the pharynx.
   b. Superior laryngeal nerve which divides into the external and internal laryngeal nerves.
   c. Ascending pharyngeal artery.

5. *Above the carotid triangle*, the external carotid artery lies deep in the substance of the parotid gland. Within the gland, it is related superficially to the retromandibular vein and the facial nerve. Deep to the external carotid artery, there are:
    a. Internal carotid artery.
    b. Structures passing between the external and internal carotid arteries; these being styloglossus, stylopharyngeus both arising from the styloid process, IX nerve, pharyngeal branch of X nerve.
    c. Two structures deep to the internal carotid artery, namely the superior laryngeal nerve and the superior cervical sympathetic ganglion.

Branches (Fig. 4.13, Flowchart 4.5)

Medial

1. Ascending pharyngeal (1st branch)

Anterior

2. Superior thyroid
3. Lingual
4. Facial

Posterior

5. Occipital
6. Posterior auricular

Terminal

7. Maxillary
8. Superficial temporal.

[*Mnemonics*: ***External carotid artery branches:*** **S**ome **A**natomists **L**ike **F**reaking **O**ut **P**oor **M**edical: **S**tudents; **S**uperior thyroid; **A**scending pharyngeal; **L**ingual; **F**acial; **O**ccipital; **P**osterior auricular; **M**axillary; **S**uperficial temporal]

Ascending Pharyngeal Artery

This is a small branch that arises from the medial side of the external carotid artery. It arises very close to the lower end of external carotid artery. It runs vertically upwards between the side wall of the pharynx, the tonsil, medial wall of the middle ear and the auditory tube.

Branches: It gives:

1. ***Pharyngeal branches*** to the pharynx, tonsil, pharyngeal ends of auditory tube, and soft palate.
2. ***Inferior tympanic branch*** to the medial wall of tympanic cavity. These branches enter the middle ear through a canaliculus for the tympanic branches of glossopharyngeal nerve.
3. ***Meningeal branches*** that enter the cranial cavity through foramen lacerum, jugular foramen and hypoglossal canal.

Superior Thyroid Artery

It arises from the external carotid artery just below the level of the greater cornua of the hyoid bone.

It runs downwards and forwards parallel and just superficial to the external laryngeal nerve. It passes deep to the three long infrahyoid muscles to reach the upper pole of the lateral lobe of the thyroid gland.

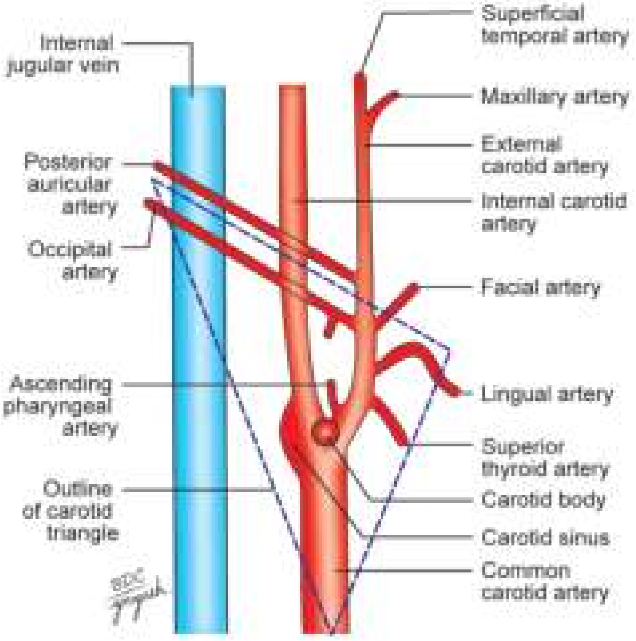
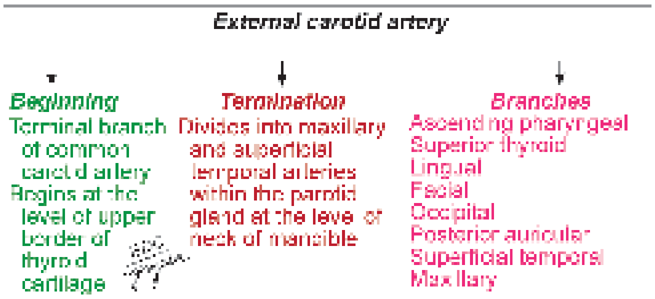

Internal jugular vein
Posterior auricular artery
Occipital artery
Ascending pharyngeal artery
Outline of carotid triangle
Superficial temporal artery
Maxillary artery
External carotid artery
Internal carotid artery
Facial artery
Lingual artery
Superior thyroid artery
Carotid body
Carotid sinus
Common carotid artery

Fig. 4.13: Right carotid arteries including branches of the external carotid artery

Flowchart 4.5: External carotid artery


External carotid artery
Beginning
Terminal branch of common carotid artery
Begins at the level of upper border of thyroid cartilage
Termination
Divides into maxillary and superficial temporal arteries within the parotid gland at the level of neck of mandible
Branches
Ascending pharyngeal
Superior thyroid
Lingual
Facial
Occipital
Posterior auricular
Superficial temporal
Maxillary

Branches: It gives:

1. *Infrahyoid branch* that runs along the lower border of hyoid bone.
2. *Superior laryngeal artery* that pierces the thyrohyoid membrane along with the internal laryngeal nerve. It supplies larynx.
3. *Cricothyroid branch* that anastomosis with similar branches of opposite sides.
4. *Sternocleidomastoid branch* to sternocleidomastoid muscle.
5. *Terminal branches*: The superior thyroid artery divides into anterior and posterior branches that supply thyroid gland.

Note: The superior thyroid artery and external laryngeal nerve diverge from each other as the artery approaches the thyroid gland. Hence, in thyroid gland surgeries, the superior thyroid artery is ligated near the gland to avoid injury to the nerve.

Lingual Artery

The lingual artery arises from the external carotid artery opposite the tip of the greater cornua of the hyoid bone.

Course: It is tortuous in its course. Its course is divided into three parts by the hyoglossus muscle, as follows:

1. ***1st part*** lies in the carotid triangle. It forms a characteristic upward loop which is crossed by the hypoglossal nerve. The lingual loop permits free movements of the hyoid bone.
2. ***2nd part*** lies deep to the hyoglossus along the upper border of hyoid bone. It is superficial to the middle constrictor of the pharynx.
3. ***3rd part*** is called the arteria profunda linguae, or the *deep lingual artery*. It runs upwards along the anterior border of the hyoglossus.
4. ***4th part:*** Finally, the artery runs horizontally forwards on the undersurface of the tongue as the ***4th part*** which is accompanied by the lingual nerve.

Branches: It gives:

1. *Suprahyoid artery* which passes along the upper border of hyoid bone.
2. *Dorsal lingual artery* (3–4 in number) arises from the second part of the artery. They supply dorsal surface of tongue, palatine tonsil, and soft palate.
3. *Sublingual artery* arises from third part to supply sublingual gland and floor of the mouth.

Note: During surgeries of the tongue (surgical removal), the lingual artery is ligated before it gives any branch to the tongue or tonsil.

Facial Artery

The facial artery arises from the external carotid just above the tip of the greater cornua of the hyoid bone. It runs upwards first in the neck as cervical part and then on the face as facial part. The course of the artery in both places is tortuous. The tortuosity in the neck allows free movements of the pharynx during deglutition. On the face, it allows free movements of the mandible, the lips and the cheek during mastication and during various facial expressions. The artery escapes traction and pressure during these movements.

The ***cervical part*** of the facial artery runs upwards on the superior constrictor of pharynx deep to the posterior belly of the digastric, stylohyoid and to the ramus of the mandible.

It grooves the posterior end of the submandibular salivary gland. Next, the artery makes an S bend (two loops) first winding down over the submandibular gland, and then up over the base of the mandible (*see* Fig. 7.11).

The ***facial part*** of the facial artery enters the face at anteroinferior angle of masseter muscle, runs upwards close to angle of mouth, side of nose till medial angle of eye.

Branches: It gives:

Branches from cervical part:

1. *Ascending palatine artery*: It arises near the origin of the facial artery and ascends upward between styloglossus and stylopharyngeus. It winds around the upper border of the superior constrictor. It supplies tonsil, soft palate, pharynx, and auditory tube.
2. *Tonsillar artery*: It is the chief supply of the tonsil. It pierces the superior constrictor to reach the tonsil.
3. *Glandular branches* for submandibular gland.
4. *Submental artery* accompanies the mylohyoid nerve. It runs along the lower border of the mandible.

Branches from facial part:

1. Inferior labial artery
2. Superior labial artery
3. Lateral nasal artery.

Occipital Artery

The occipital artery arises from the posterior aspect of the external carotid artery, opposite the origin of the facial artery. It is crossed by the hypoglossal nerve.

Branches: It gives:

1. *Sternomastoid branches*: Upper sternomastoid branch accompanies the spinal accessory nerve. Lower sternomastoid branch loops around the hypoglossal nerve.
2. *Mastoid branch* enters the mastoid foramen to supply mastoid air cells and meninges.
3. *Meningeal branches* enter the cranial cavity through jugular foramen and condylar canals.
4. *Muscular branches*
5. *Descending branch*: It divides into
   a. *Superficial branch* which anastomoses with superficial branch of transverse cervical artery.
   b. *Deep branch* which anastomoses with deep cervical artery.
6. *Occipital branches* to scalp.

Posterior Auricular Artery

The posterior auricular artery arises from the posterior aspect of the external carotid just above the posterior belly of the digastric. It runs upwards and backwards deep to the parotid gland, but superficial to the styloid process. It crosses the base of the mastoid process and ascends behind the auricle.

Branches: It gives:

1. *Stylomastoid branch* enters the stylomastoid foramen and supplies the middle ear, mastoid antrum, air cells and facial nerve.
2. *Auricular branch* supplies the auricle.
3. *Occipital branch* supplies the scalp.

Maxillary Artery

This is the larger terminal branch of the external carotid artery. It begins behind the neck of the mandible under cover of the parotid gland. It runs forwards deep to the neck of the mandible below the auriculotemporal nerve and enters the infratemporal fossa where it will be studied at a later stage.

Superficial Temporal Artery

It is the smaller terminal branch of the external carotid artery. It begins, behind the neck of the mandible under cover of the parotid gland. It runs vertically upwards, crossing the root of the zygoma or preauricular point, where its *pulsations* can be easily felt. About 5 cm above the zygoma, it divides into anterior and posterior branches.

Branches: It gives:

1. *Transverse facial artery* arises from the superficial temporal artery within the parotid gland. It passes forward along with the zygomatic branch of the facial nerve. It supplies parotid gland, temporomandibular joint and face.
2. *Anterior auricular branch* to the auricle and external acoustic meatus.
3. Zygomatico-orbital branch to the face.
4. *Middle temporal artery* pierces the temporal fascia to supply temporalis.
5. Anterior and posterior divisions supply temple, scalp and auricle.

POTENTIAL TISSUE SPACES IN HEAD AND NECK

1. ***Submental space:*** Lies below inferior border of mandible. Corresponds to submental triangle. It communicates with submandibular spaces on both sides.
2. ***Submandibular space:*** Lies between anterior and posterior bellies of digastric muscle and inferior border of mandible. It communicates with sublingual and submental spaces.
3. ***Parotid space:*** Localised around parotid gland behind ramus of mandible, communicates with retropharyngeal space and even mediastinum.
4. ***Parapharyngeal space:*** Lies in suprahyoid region of neck, lateral to pharynx. It is continuous with retropharyngeal space.
5. ***Retropharyngeal space:*** Lies between anteriorly placed buccopharyngeal fascia and posteriorly placed prevertebral fascia. It communicates with peritonsillar space, submental spaces and may reach mediastinum.
6. ***Peritonsillar space:*** Lies between anterior and posterior fauces of the palatine tonsil. It communicates with sublingual space.

VIDEO

Video 3.4 Anterior Triangle of the Neck

Facts to Remember

- Apex of anterior triangle of neck is close to the sternum, while that of posterior triangle is close to the mastoid process.
- Submental triangle is half on each side of the midline.
- Maximum blood vessels are present in the carotid triangle.
- Superficial temporal artery can be palpated at the preauricular point.
- The necktie should not be tied tightly, as it may compress both the internal carotid arteries, supplying the brain.

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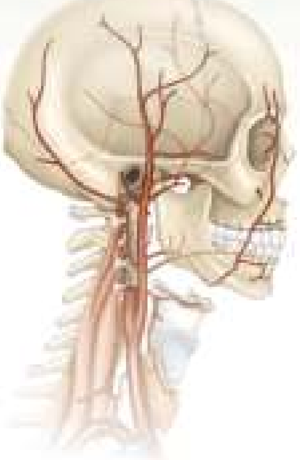
1. Subhyoid bursa
2. Lingual artery
3. Further reading
4. Viva voce questions



Chapter 5

Parotid Region

The parotid region is a region located on the posterolateral side of the face. It contains the parotid gland and facial nerve. The boundaries of the parotid region are as follows:

Anteriorly: Posterior border of ramus of mandible masseter and medial pterygoid muscles
Posteriorly: Mastoid process
Sternocleidomastoid muscle
Superiorly: External acoustic meatus
Posterior part of temporomandibular joint
Medially: Styloid process
Styloid group of muscles.

Facial nerve is described in detail in Chapter 6, *BD Chaurasia's Human Anatomy, Volume 4*. Its extracranial course is given in this chapter.

SALIVARY GLANDS

There are three pairs of large salivary glands—the parotid, submandibular and sublingual. In addition, there are numerous small glands in the tongue, the palate, the cheeks and the lips. These glands produce saliva which keeps the oral cavity moist and helps in chewing and swallowing. The saliva also contains enzymes that aid digestion.

Competency:
AN28.9 Describe and demonstrate the parts, borders, surfaces, contents, relations and nerve supply of parotid gland with course of its duct and surgical importance.

PAROTID GLAND

The parotid gland is the largest of the salivary glands (*Para* = around; *otic* = ear). It weighs about 25 g.

Location

The parotid glands are situated in the pyramidal *retromandibular fossa* or ***parotid bed*** (Fig. 5.1). The boundaries of the parotid bed are as follows:

Anteriorly: Ramus of mandible with medial pterygoid and masseter
Posteriorly: Mastoid process with sternocleidomastoid and posterior belly of digastric
Superiorly: External acoustic meatus and temporomandibular joint
Medially: Styloid apparatus

The gland overlaps these structures. Skin over the gland is supplied by great auricular nerve (C2, C3).

Capsule of Parotid Gland

The investing layer of the deep cervical fascia forms a capsule or ***parotid sheath*** (Fig. 5.2). It is supplied by great auricular nerve.

The parotid sheath has two laminae:

a. *Superficial lamina* is thick, strong, unyielding and adherent to the glands. Superiorly, it is attached to the inferior border of the zygomatic arch. Anteriorly, it blends with the epimysium of masseter to form *parotidomasseteric fascia*.
b. *Deep lamina* is thin. It is attached to the tympanic plate and styloid process. *Stylomandibular ligament* is a thickened part of deep lamina that extends from the tip of styloid process to the angle of mandible.

Note: Recent concept:
The ***superficial Musculo-aponeurotic system*** (SMAS) is a single tissue plane in the face. It is composed of muscle fibres and fibrous or fibroaponeurotic tissue. It is not directly attached to bone.

Inferiorly, it becomes continuous with platysma in the neck. The superficial layer of the parotid capsule is a component of the SMAS, and not from the investing layer of deep cervical fascia [*Reference*: Gary's Anatomy, 42nd ed].

CLINICAL ANATOMY

- ***Parotid swellings*** are very painful due to the unyielding nature of the parotid fascia.
- ***Mumps*** is an infectious disease of the salivary glands (usually the parotid) caused by a specific virus. Viral parotitis or mumps characteristically does not suppurate. Its complications are orchitis and pancreatitis (Fig. 5.3).
- ***Accessory parotid gland*** is a detached part of the parotid gland that lies between the zygomatic arch and the parotid duct. It drains into the main parotid duct.

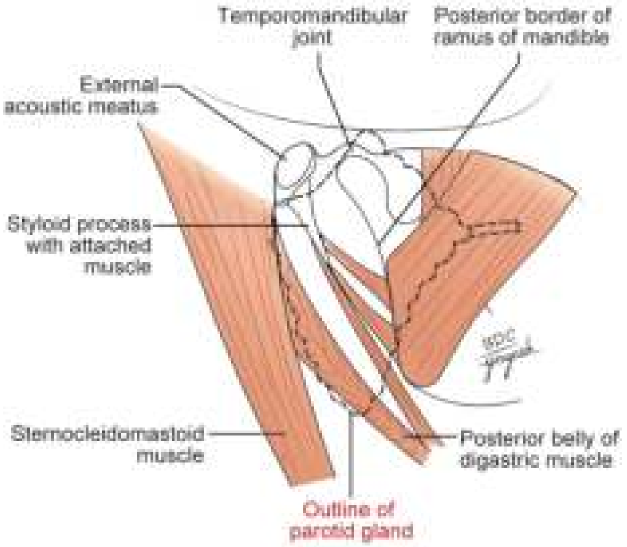

Temporomandibular joint
Posterior border of ramus of mandible
External acoustic meatus
Styloid process with attached muscle
Sternocleidomastoid muscle
Posterior belly of digastric muscle
Outline of parotid gland

Fig. 5.1: Location of parotid gland

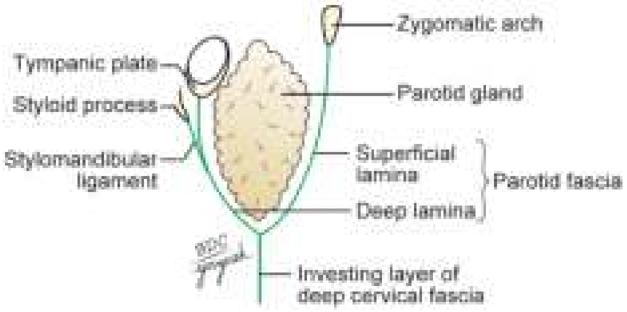

Zygomatic arch
Tympanic plate
Styloid process
Parotid gland
Stylomandibular ligament
Superficial lamina
Deep lamina
Parotid fascia
Investing layer of deep cervical fascia

Fig. 5.2: Parotid capsule (coronal section)

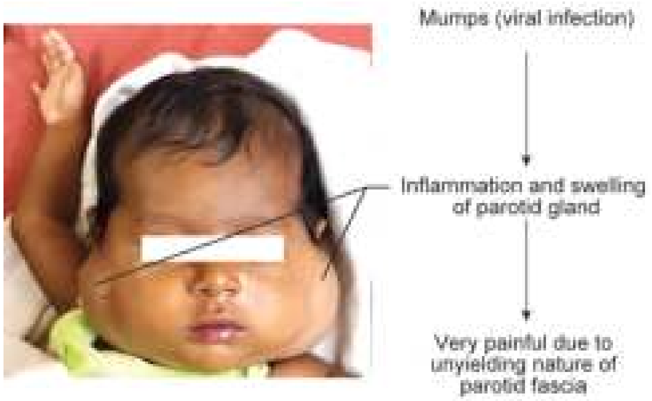

Mumps (viral infection)
Inflammation and swelling of parotid gland
Very painful due to unyielding nature of parotid fascia

Fig. 5.3: Mumps (*Image courtesy*: Dr Jaikumar GR)

External Features

The parotid gland resembles an inverted pyramid with apex directed downward (Figs 5.4a and b, Flowchart 5.1). The gland presents:

- Apex
- *Four surfaces*:
  1. Superior surface (base)
  2. Superficial
  3. Anteromedial
  4. Posteromedial
- *Three borders*:
  1. Anterior
  2. Posterior
  3. Medial.

Relations (Plate 5.1, Figs 5.5 to 5.7, Flowchart 5.2)

Apex

The apex is directed downwards. It overlaps the posterior belly of the digastric.

Structures emerging through apex:

1. Cervical branch of the facial nerve
2. Anterior and posterior divisions of the retromandibular vein.

Superior Surface or Base

It forms the upper end of the gland which is small and concave.

It is related to:

1. External acoustic meatus
2. Posterior surface of the temporomandibular joint.

Structures emerging through the superior surface:

1. Superficial temporal vessels.
2. Auriculotemporal nerve.

Superficial Surface

It is the largest of the four surfaces. It is covered with:

1. Skin
2. Superficial fascia containing the anterior branches of the great auricular nerve, the preauricular or superficial parotid lymph nodes and the posterior fibres of the platysma and risorius
3. Superficial lamina of the parotid fascia
4. A few deep parotid lymph nodes embedded in the gland.

Anteromedial Surface

It is grooved by the posterior border of the ramus of the mandible. It is related to:

1. Masseter
2. Lateral surface of the temporomandibular joint
3. Posterior border of the ramus of the mandible
4. Medial pterygoid
5. Emerging branches of the facial nerve and maxillary artery.

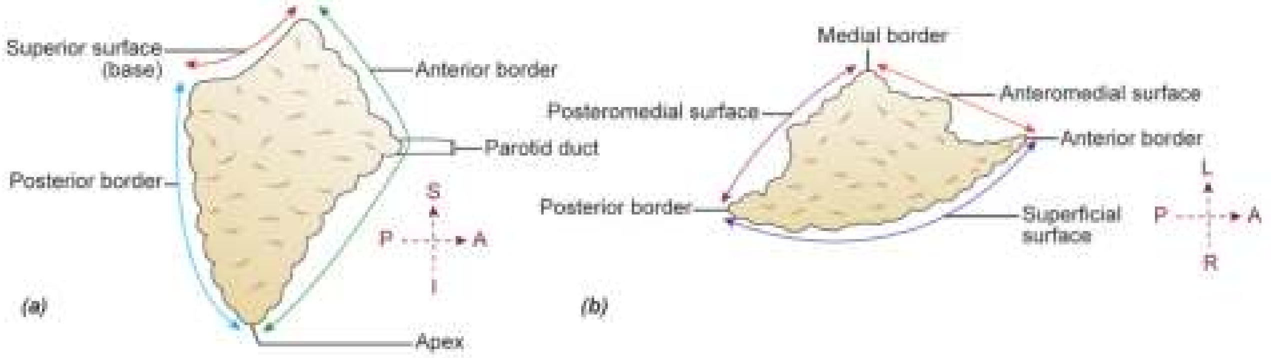
Posteromedial Surface

It is moulded to the mastoid and the styloid processes and the structures attached to them. Thus, it is related to:

1. Mastoid process, with the sternocleidomastoid and the posterior belly of the digastric.
2. Styloid process, with structures attached to it.
3. Deep to styloid apparatus: Internal carotid artery, internal jugular vein, last 4 cranial nerves.

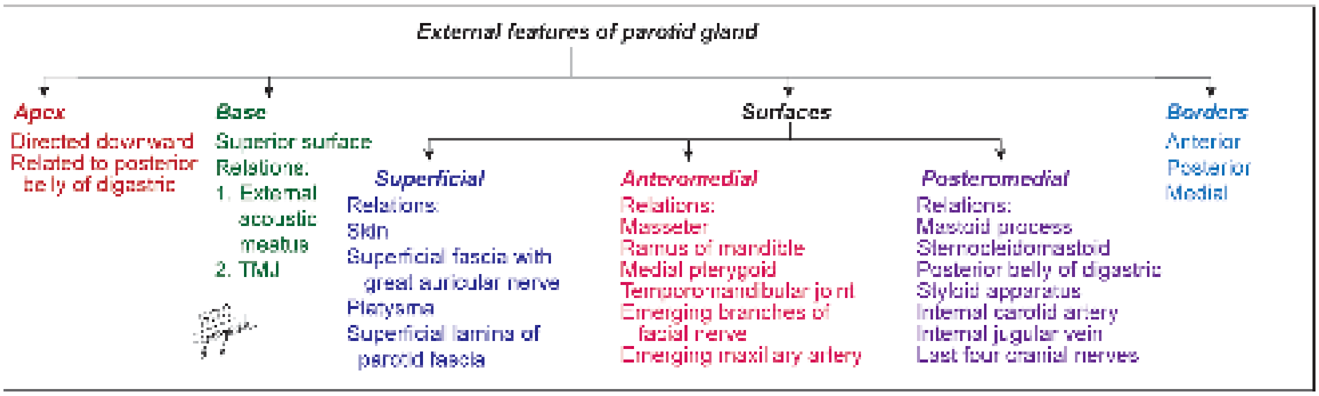
Structures entering through posteromedial surface:

1. Facial nerve
2. External carotid artery


Superior surface (base)
Anterior border
Parotid duct
Posterior border
S
P
A
I
(a)
Apex
Medial border
Anteromedial surface
Posteromedial surface
Anterior border
Posterior border
Superficial surface
L
P
A
R
(b)

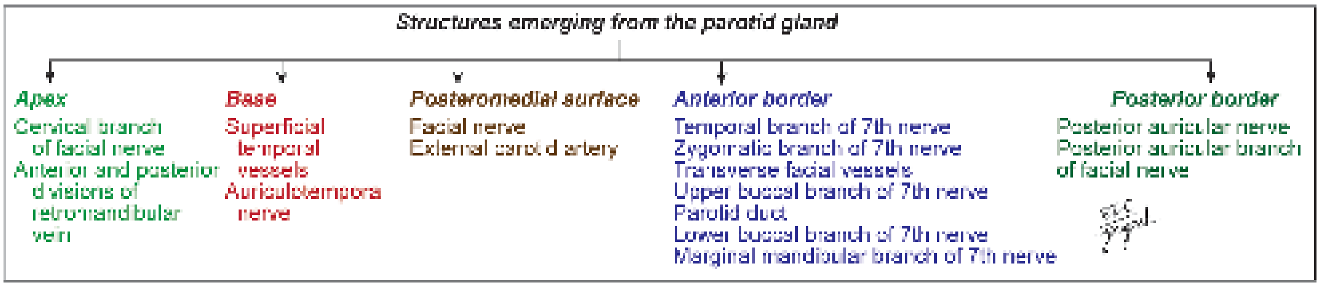
Figs 5.4a and b: External features of parotid gland: (a) Lateral view and (b) horizontal section through parotid gland

Flowchart 5.1: Parotid gland: External features


External features of parotid gland
Apex
Directed downward
Related to posterior belly of digastric
Base
Superior surface
Relations:
1. External acoustic meatus
2. TMJ
Surfaces
Superficial
Relations:
Skin
Superficial fascia with great auricular nerve
Platysma
Superficial lamina of parotid fascia
Anteromedial
Relations:
Masseter
Ramus of mandible
Medial pterygoid
Temporomandibular joint
Emerging branches of facial nerve
Emerging maxillary artery
Posteromedial
Relations:
Mastoid process
Sternocleidomastoid
Posterior belly of digastric
Styloid apparatus
Internal carotid artery
Internal jugular vein
Last four cranial nerves
Borders
Anterior
Posterior
Medial

(TMJ: Temporomandibular joint)

Flowchart 5.2: Structures emerging from the parotid gland


Structures emerging from the parotid gland
Apex
Cervical branch of facial nerve
Anterior and posterior divisions of retromandibular vein
Base
Superficial temporal vessels
Auriculotemporal nerve
Posteromedial surface
Facial nerve
External carotid artery
Anterior border
Temporal branch of 7th nerve
Zygomatic branch of 7th nerve
Transverse facial vessels
Upper buccal branch of 7th nerve
Parotid duct
Lower buccal branch of 7th nerve
Marginal mandibular branch of 7th nerve
Posterior border
Posterior auricular nerve
Posterior auricular branch of facial nerve

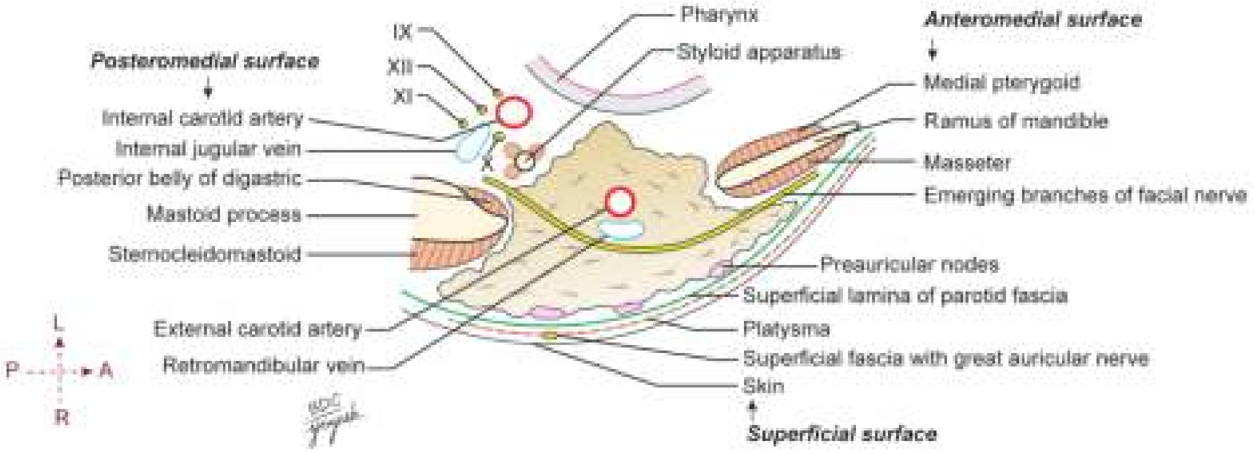
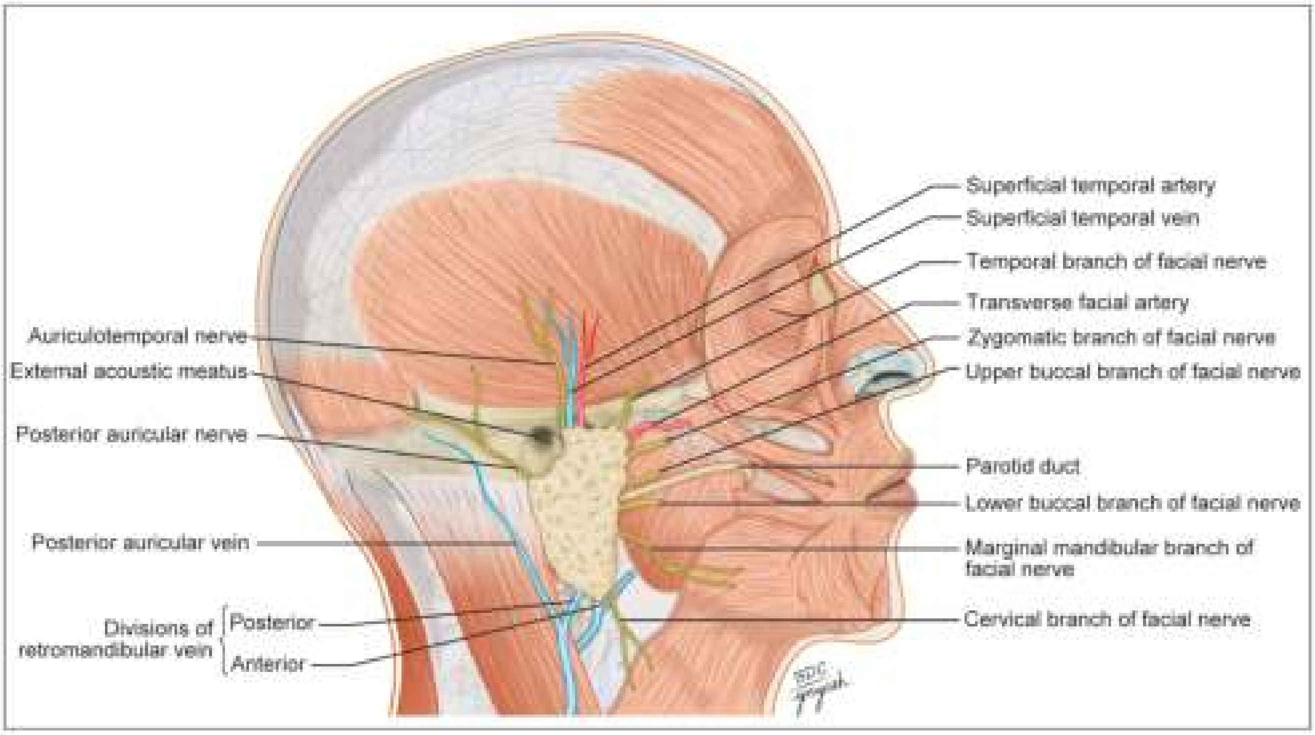

Posteromedial surface
Internal carotid artery
Internal jugular vein
Posterior belly of digastric
Mastoid process
Sternocleidomastoid
External carotid artery
Retromandibular vein
IX
XII
XI
X
Pharynx
Styloid apparatus
Anteromedial surface
Medial pterygoid
Ramus of mandible
Masseter
Emerging branches of facial nerve
Preauricular nodes
Superficial lamina of parotid fascia
Platysma
Superficial fascia with great auricular nerve
Skin
Superficial surface
L
P
A
R

Fig. 5.5: Relations of the parotid gland

Plate 5.1: The structures emerging at the periphery of the parotid gland


Superficial temporal artery
Superficial temporal vein
Temporal branch of facial nerve
Transverse facial artery
Zygomatic branch of facial nerve
Upper buccal branch of facial nerve
Auriculotemporal nerve
External acoustic meatus
Posterior auricular nerve
Parotid duct
Lower buccal branch of facial nerve
Posterior auricular vein
Marginal mandibular branch of facial nerve
Divisions of retromandibular vein
Posterior
Anterior
Cervical branch of facial nerve
SDC

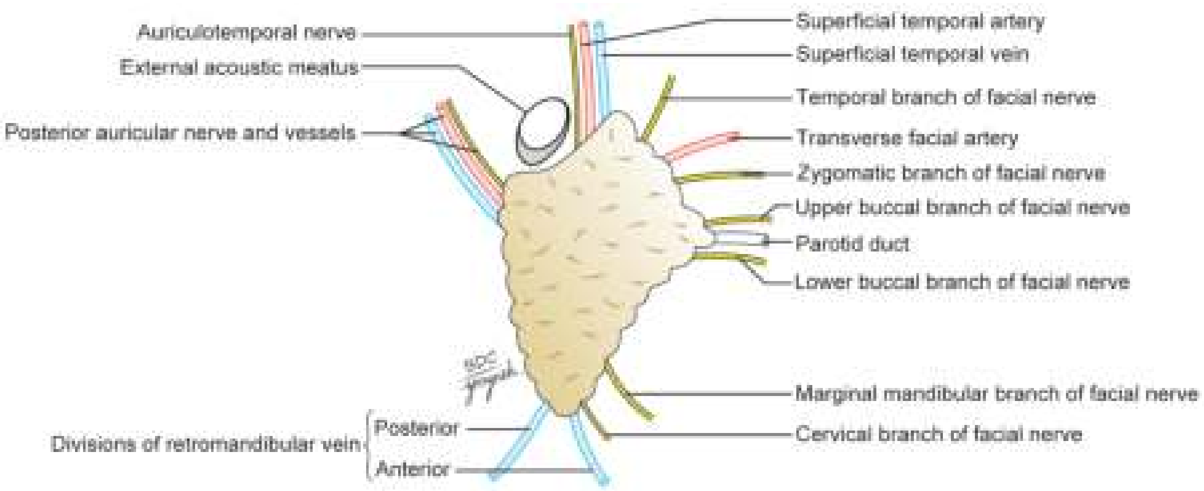

Auriculotemporal nerve
External acoustic meatus
Posterior auricular nerve and vessels
Superficial temporal artery
Superficial temporal vein
Temporal branch of facial nerve
Transverse facial artery
Zygomatic branch of facial nerve
Upper buccal branch of facial nerve
Parotid duct
Lower buccal branch of facial nerve
Marginal mandibular branch of facial nerve
Cervical branch of facial nerve
Divisions of retromandibular vein
Posterior
Anterior
SDC

Fig. 5.6: Structures emerging at the periphery of the parotid gland

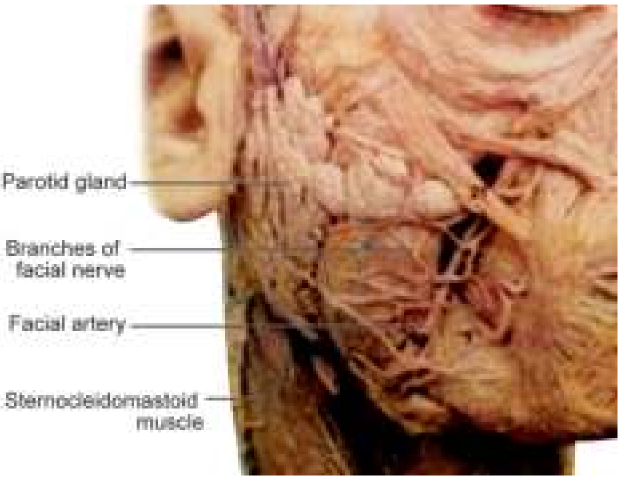

Parotid gland
Branches of facial nerve
Facial artery
Sternocleidomastoid muscle

Fig. 5.7: Parotid gland

Anterior Border

It separates the superficial surface from the anteromedial surface. It extends from the anterior part of the superior surface to the apex.

Structures emerging from the anterior border from above downward:

1. Temporal branch of facial nerve
2. Zygomatic branch of facial nerve
3. Transverse facial vessels
4. Upper buccal branch of facial nerve
5. Parotid duct
6. Lower buccal branch of facial nerve
7. Marginal mandibular branch of facial nerve.

In addition, the accessory parotid glands' facial process lies on the parotid duct close to this border.

Posterior Border

It separates the superficial surface from the posteromedial surface. It overlaps the sternocleidomastoid.

Structures emerging deep to posterior border:

1. Posterior auricular nerve
2. Posterior auricular branch of facial nerve.

Medial Edge or Pharyngeal Border

It separates the anteromedial surface from the posteromedial surface. It is related to the lateral wall of the pharynx.

Structures within the Parotid Gland

Three main structures are present within the parotid gland. From superficial to deep, they are as follows (Figs 5.8a to c, Flowchart 5.2):

1. Facial nerve and its branches
2. Retromandibular vein
3. External carotid artery.

Facial Nerve

The facial nerve enters the posteromedial surface of the parotid gland, and runs forward through the gland crossing the retromandibular vein and the external carotid artery. Behind the neck of the mandible, the divides into two branches – temporofacial and cervicofacial. These form a plexus called *pes anserinus,* which gives 5 terminal branches, e.g. temporal, zygomatic, buccal, marginal mandibular and cervical which emerge along the anterior border and apex of the parotid gland (Fig. 5.8a).

Arteries

The ***external carotid artery*** enters the gland through its posteromedial surface (Fig. 5.5c). The ***maxillary artery*** leaves the gland through its anteromedial surface. The ***superficial temporal artery*** gives transverse facial artery and emerges at the anterior part of the superior surface.

Veins

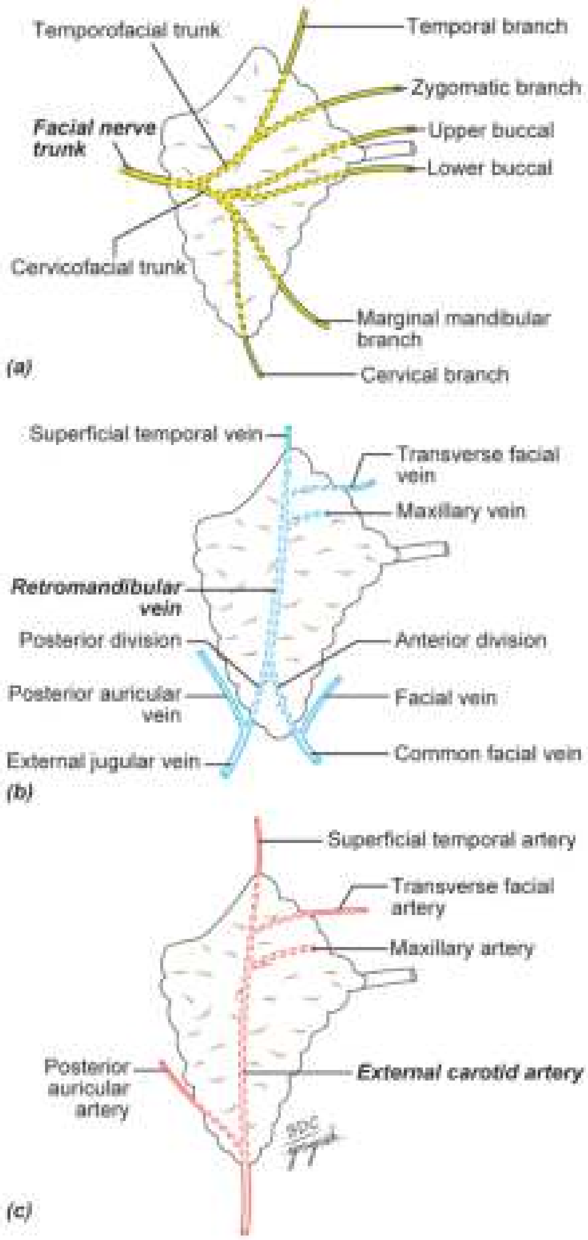
The ***retromandibular vein*** is formed within the gland by the union of the ***superficial temporal*** and ***maxillary veins***. In the lower part of the gland, the vein divides into *anterior and posterior divisions* which emerge close to the apex (lower pole) of the gland (Fig. 5.5b).

Accessory Processes of Parotid Gland

- Facial process—along parotid duct. It lies between zygomatic arch and the parotid duct.
- Pterygoid process—between mandibular ramus and medial pterygoid.
- Glenoid process—between external acoustic meatus and temporomandibular joint.
- Poststyloid process.

Blood Supply

The parotid gland is supplied by the external carotid artery and its branches that arise within the gland. The veins drain into the external jugular vein and internal jugular vein.


Temporofacial trunk
Temporal branch
Zygomatic branch
Facial nerve trunk
Upper buccal
Lower buccal
Cervicofacial trunk
Marginal mandibular branch
Cervical branch
(a)
Superficial temporal vein
Transverse facial vein
Maxillary vein
Retromandibular vein
Posterior division
Anterior division
Posterior auricular vein
Facial vein
External jugular vein
Common facial vein
(b)
Superficial temporal artery
Transverse facial artery
Maxillary artery
Posterior auricular artery
External carotid artery
(c)

Figs 5.8a to c: The structures traversing the parotid gland: (a) Facial nerve (pes anserinus branching pattern), (b) retromandibular vein, and (c) external carotid artery

Lymphatic Drainage

Lymph drains first to the parotid nodes and from there to the upper deep cervical nodes.

Nerve Supply (Fig. 5.9, Flowchart 5.3)

1. ***Parasympathetic nerves*** are secretomotor. They reach the gland through the auriculotemporal nerve.

   The *preganglionic fibres* begin in the inferior salivatory nucleus; pass through the glossopharyngeal nerve, its tympanic branch, the tympanic plexus and the lesser petrosal nerve; and relay in the otic ganglion.

   The *postganglionic fibres* pass through the auriculotemporal nerve and reach the gland.
2. ***Sympathetic nerves*** are postganglionic, vasomotor, and are derived from the plexus around the middle

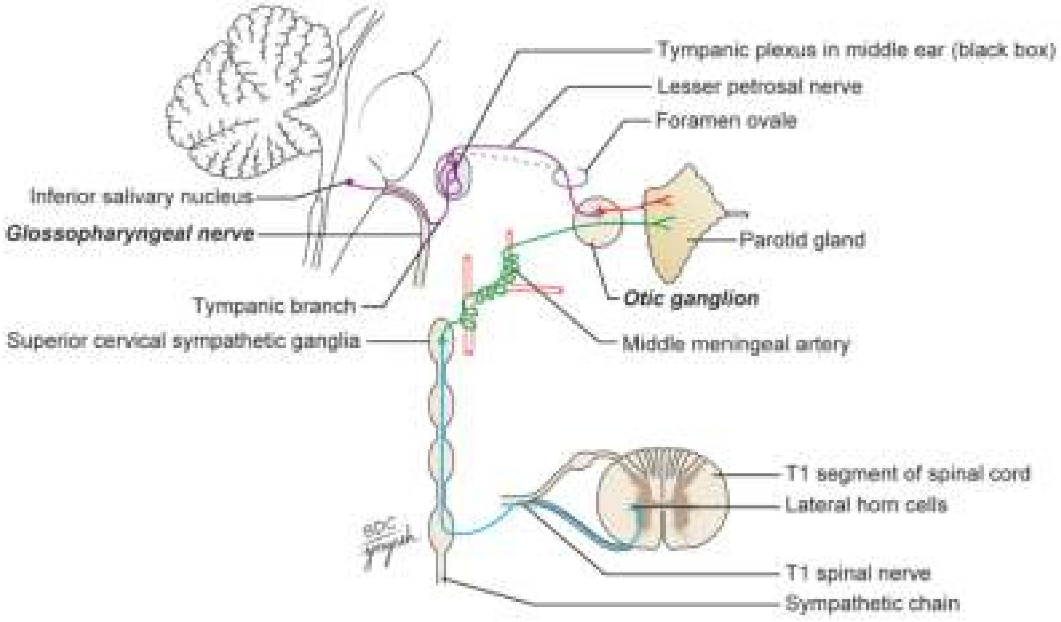
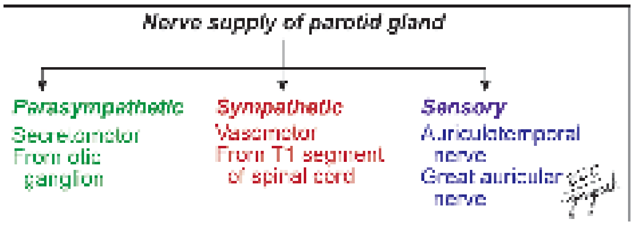

Tympanic plexus in middle ear (black box)
Lesser petrosal nerve
Foramen ovale
Inferior salivary nucleus
Glossopharyngeal nerve
Parotid gland
Tympanic branch
Otic ganglion
Superior cervical sympathetic ganglia
Middle meningeal artery
T1 segment of spinal cord
Lateral horn cells
T1 spinal nerve
Sympathetic chain

Fig. 5.9: Innervation of parotid gland (schematic representation, Purple line): Preganglionic parasympathetic fibres, Red line: Postganglionic parasympathetic fibres, Blue line: Preganglionic sympathetic fibres, Green line: Postganglionic sympathetic fibres, *Note*: Lesser petrosal nerve enter the middle cranial fossa and exit through the foramen ovale. Middle cranial fossa shown by grey dotted line

Flowchart 5.3: Nerve supply of parotid gland


Nerve supply of parotid gland
Parasympathetic
Secretomotor
From otic ganglion
Sympathetic
Vasomotor
From T1 segment of spinal cord
Sensory
Auriculotemporal nerve
Great auricular nerve

meningeal artery. These fibres start from lateral horn of T1 segment of spinal cord. These synapse in superior cervical ganglion. Postganglionic fibres travel along branches of external carotid, maxillary arteries and their branches, e.g. middle meningeal artery.

3. ***Sensory nerves*** to the gland come from the auriculotemporal nerve, but the parotid fascia is innervated by the sensory fibres of the great auricular nerve (C2, C3).

PAROTID LYMPH NODES

The parotid lymph nodes lie partly in the superficial fascia and partly deep to the deep fascia over the parotid gland. They drain:

1. Temple
2. Side of the scalp
3. Lateral surface of the auricle
4. External acoustic meatus
5. Middle ear
6. Parotid gland
7. Upper part of the cheek
8. Parts of the eyelids and orbit.

Efferents from these nodes pass to the upper group of deep cervical nodes.

PAROTID DUCT/STENSON'S DUCT

(Figs 5.10 and 5.11, Flowchart 5.4)

Parotid or Stenson's duct is thick-walled and is about 5 cm long [Nicolaus Steno, Dutch Anatomist, 1638–86].

Course

It emerges from the middle of the anterior border of the gland. It runs forwards and slightly downwards on the masseter.

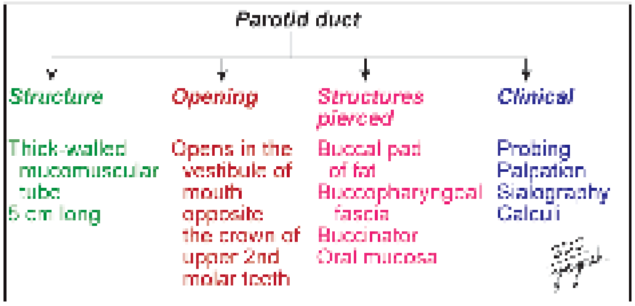
After emerging from the parotid gland, the duct runs forward on the masseter, between the upper and lower buccal nerves. Then, it runs medially along the anterior border of masseter and pierces:

1. Buccal pad of fat
2. Buccopharyngeal fascia
3. Buccinator
4. Oral mucosa.

Before piercing the mucosa, the duct runs obliquely forward and opens into the vestibule of mouth opposite the crown of upper 2nd molar tooth.

Note: This typical course of the duct prevents air entry in the duct during blowing of mouth (as in trumpet blowing).

Flowchart 5.4: Parotid duct


Parotid duct
Structure
Thick-walled mucomuscular tube
5 cm long
Opening
Opens in the vestibule of mouth opposite the crown of upper 2nd molar tooth
Structures pierced
Buccal pad of fat
Buccopharyngeal fascia
Buccinator
Oral mucosa
Clinical
Probing
Palpation
Sialography
Calculi

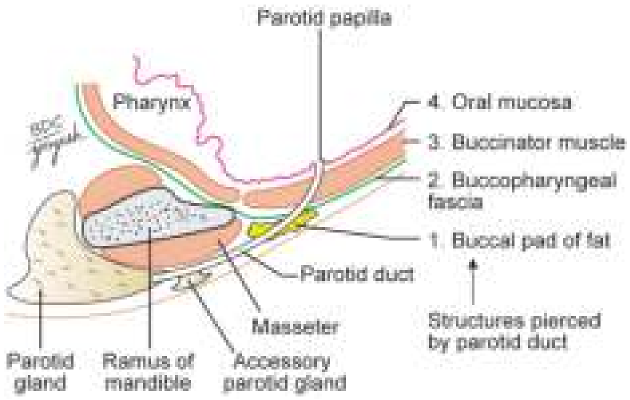

Parotid papilla
Pharynx
4. Oral mucosa
3. Buccinator muscle
2. Buccopharyngeal fascia
1. Buccal pad of fat
Parotid duct
Structures pierced by parotid duct
Masseter
Parotid gland
Ramus of mandible
Accessory parotid gland

Fig. 5.10: Structures pierced by parotid duct

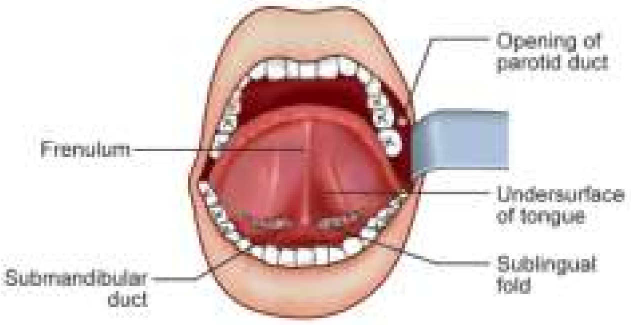

Opening of parotid duct
Frenulum
Undersurface of tongue
Sublingual fold
Submandibular duct

Fig. 5.11: Openings of salivary glands

Competency:
AN28.10 Explain the anatomical basis of Frey's syndrome.

CLINICAL ANATOMY

- Probing the parotid duct is difficult due to its tortuous course.
- ***Palpation of parotid duct:*** The parotid duct can be rolled up and down against the tense-masseter on clinching of teeth. The duct lies about one fingerbreadth below the zygomatic arch.
- ***Parotid sialography*** is a radiological visualisation of the parotid duct and its tributaries by injecting radio-opaque into the parotid duct through its oral opening.
- A *parotid abscess* may be caused by spread of infection from the opening of parotid duct in the mouth cavity (Fig. 5.12).
- ***Parotid abscess*** can be drained by horizontal incision/making many small holes known as Hilton's method (Fig. 5.12) below the angle of mandible.
- **Parotidectomy** is the removal of the parotid gland.
- ***Mixed parotid tumour*** is a slow growing lobulated painless tumour without any involvement of the facial nerve. Malignant change of such a tumour is indicated by pain, rapid growth, fixity with hardness, involvement of the facial nerve, and enlargement of cervical lymph nodes.
- The ***parotid calculi*** may get formed within the parotid gland or in its Stenson's duct. These can be located by injecting a radio-opaque dye through its opening in the vestibule of the mouth.

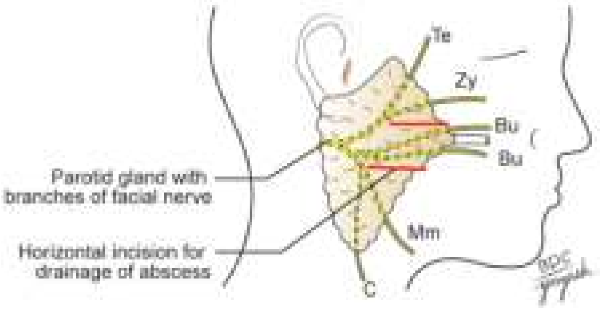

Te
Zy
Bu
Bu
Mm
C
Parotid gland with branches of facial nerve
Horizontal incision for drainage of abscess

Fig. 5.12: Horizontal incision for draining parotid abscess. Branches of facial nerve also seen. Te—temporal; Zy—zygomatic, Bu—upper and lower buccal; Mm—marginal mandibular; C—cervical

FACIAL NERVE: EXTRACRANIAL COURSE

It is the nerve of the 2nd branchial arch. The facial nerve leaves the skull by passing through the stylomastoid foramen.

In its extracranial course, the facial nerve crosses the lateral side of the base of the styloid process. Then the nerve enters the posteromedial surface of the parotid gland, runs forwards through the gland crossing the retromandibular vein and the external carotid artery.

Branches

Behind the neck of the mandible, the divides into two branches – temporofacial and cervicofacial (Fig. 5.8a). These form a plexus called *pes anserinus,* which gives 5 terminal branches, e.g. temporal, zygomatic, buccal, marginal mandibular and cervical which emerge along the anterior border and apex of the parotid gland.

Branches of Facial Nerve at its Exit from the Stylomastoid Foramen

1. Communicating branches with adjacent cranial and spinal nerves.
2. ***Posterior auricular nerve*** arises just below the stylomastoid foramen. It ascends between the mastoid process and the external acoustic meatus, and supplies:
   a. Auricularis posterior
   b. Occipitalis
   c. Intrinsic muscles on the back of auricle.
3. ***Digastric branch*** arises close to the previous nerve. It is short and supplies the posterior belly of the digastric.
4. ***Stylohyoid branch*** arises with the digastric branch, is long and supplies the stylohyoid muscle.

Terminal Branches

1. ***Temporal branches*** cross the zygomatic arch and supply:
   a. Auricularis anterior
   b. Auricularis superior
   c. Intrinsic muscles on the lateral side of the ear
   d. Frontalis

   e. Orbicularis oculi
   f. Corrugator supercilii.
2. ***Zygomatic*** *branches* run across the zygomatic bone and supply the orbicularis oculi.
3. ***Buccal*** *branches* are two in number. The upper buccal branch runs above the parotid duct and the lower buccal branch below the duct. They supply muscles in that vicinity, especially the buccinator.
4. ***Marginal mandibular*** *branch* runs below the angle of the mandible deep to the platysma. It crosses the body of the mandible and supplies muscles of the lower lip and chin.
5. ***Cervical*** *branch* emerges from the apex of the parotid gland and runs downwards and forwards in the neck to supply the platysma.

CLINICAL ANATOMY

- ***Bell's palsy:*** Sudden paralysis of facial nerve at the stylomastoid foramen, results in asymmetry of corner of mouth, inability to close the eye, disappearance of nasolabial fold and loss of wrinkling of skin of forehead on the same side.
- ***Patey's faciovenous plane:*** It is a plane that divides the parotid glands into large superficial and small deep parts or lobes. Isthmus is a part of glandular tissue present in the Patey's faciovenous plane and it connects superficial and deep parts. This plane is traversed by facial nerve and its branches and retromandibular vein. In the surgical removal of parotid gland, care should be taken along this plane (Fig. 5.13).

FREY'S SYNDROME

It is also called auriculotemporal syndrome, Frey-Baillarger syndrome [Lucja Frey, Polish neurologist, 1889–1942], or Dupuy's syndrome (Fig. 5.14).

It is a rare neurological disorder resulting in gustatory sweating.

Cause: Damage to auriculotemporal and great auricular nerves in the parotid gland injuries or surgeries.

Anatomical basis: Parasympathetic fibres of auriculotemporal nerve stimulate the parotid gland to enhance its secretion and sympathetic fibres of the great auricular nerve sweat glands in the facial skin. After damage to both nerves, during regeneration, the parasympathetic fibres of auriculotemporal nerve grow and join the sympathetic fibres of the great auricular nerve. This results in sweating rather than salivation during eating. Hence, it is called *gustatory sweating* or *Frey's syndrome*.

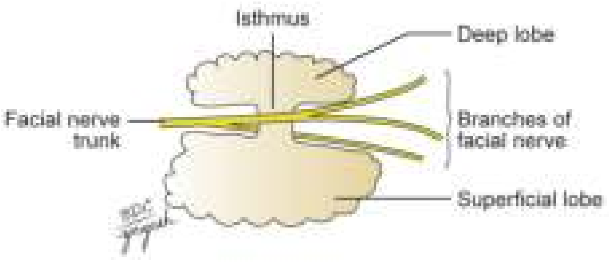


Fig. 5.13: Patey's faciovenous (neurovenous) plane in the parotid gland (Transverse section through the parotid gland, retromandibular vein is not shown for clarity)

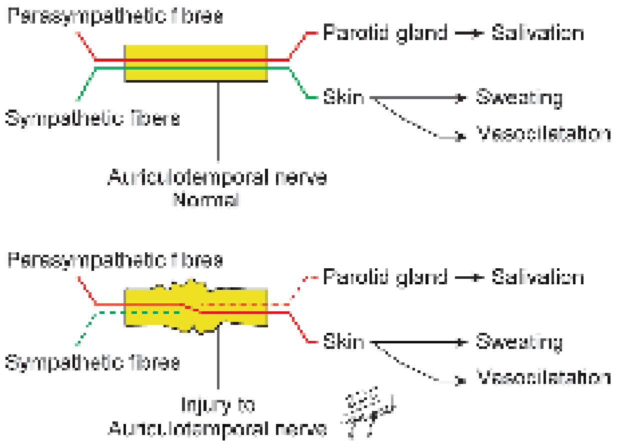


Fig. 5.14: Anatomical basis of Frey's syndrome

Histology of Parotid Gland

1. It is a large serous gland. It is a compound tubuloacinar gland. It is covered by thick capsule and divided into number of lobes and lobules (Plate 5.2).
2. *Acini*: Parotid gland consists of serous acini. These acini are surrounded by myoepithelial cells.
3. *Ducts*: Parotid gland has number of intralobular (intercalated and striated) ducts and interlobular and lobar ducts. Intercalated ducts are lined by low cuboidal epithelium. Striated ducts are lined by simple columnar epithelium with basal infoldings. These ducts are large and conspicuous in parotid gland. Other ducts are lined by stratified cuboidal to stratified squamous epithelium.
4. Large amounts of adipose tissue often occur in the parotid gland; this is one of its distinguishing features.

Development

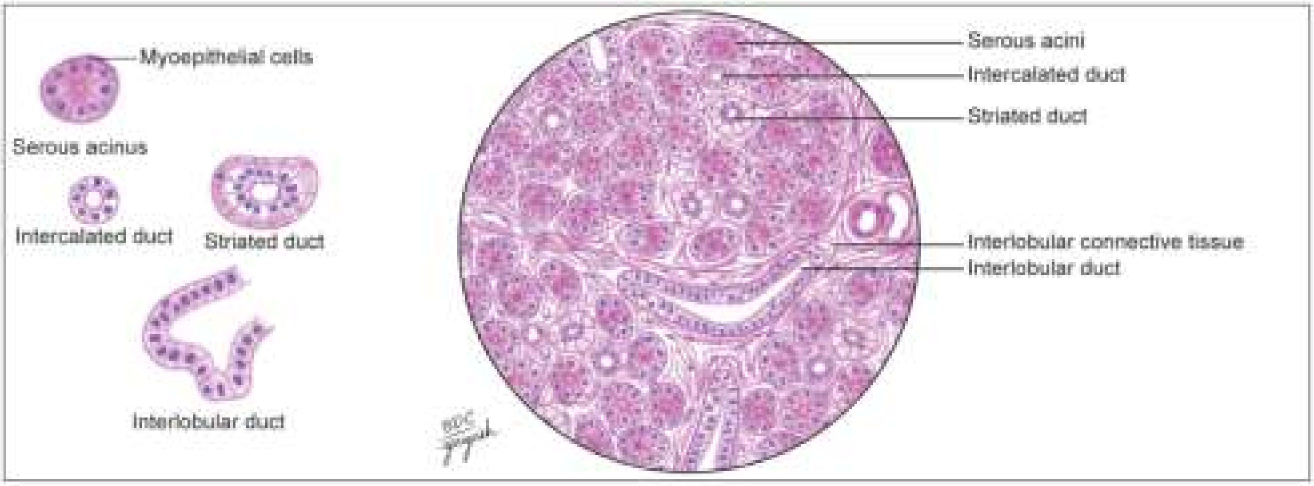
The parotid gland is ectodermal in origin. It develops from the buccal epithelium just lateral to the angle of mouth. The outgrowth branches repeatedly to form the duct system and acini. The mesoderm forms the intervening connective tissue septa.

DISSECTION

Carefully cut through the fascial covering of the parotid gland from the zygomatic arch above to the angle of mandible below. While removing tough fascia, dissect the structures emerging at the periphery of the gland.

Trace the duct of the parotid gland anteriorly till the buccinator muscle. Trace one or more of the branches of facial nerve till its trunk in the posterior part of the gland. The trunk can be followed till the stylomastoid foramen. Trace its posterior auricular branch. Trace the course of

Plate 5.2: Histology of parotid gland


Myoepithelial cells
Serous acinus
Intercalated duct
Striated duct
Interlobular duct
Serous acini
Intercalated duct
Striated duct
Interlobular connective tissue
Interlobular duct

retromandibular vein and external carotid artery in the gland, removing the glands in pieces. Clean the facial nerve already dissected. Study the extracranial course of facial nerve.

VIDEO

Video 3.5 Parotid Gland

Facts to Remember

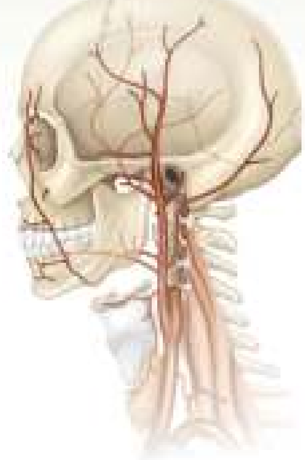
- Facial nerve courses through the parotid gland, *without supplying any structure in it.*
- Skin over the parotid gland is supplied by great auricular nerve C2, C3.
- The deepest structure in the substance of parotid gland is the external carotid artery.
- Otic ganglion is the only parasympathetic ganglion with four roots, including a motor root.
- Facial nerve divides into temporofacial and cervicofacial branches. The former gives temporal and zygomatic branches. The latter gives buccal, marginal mandibular and cervical branches.
- Parotid gland is the largest salivary gland in the body.
- Mumps is the commonest infection of the parotid gland.
- Parotid duct opens into the vestibule of mouth opposite the crown of upper 2nd molar tooth.
- Hilton's horizontal incision prevents injury to the facial nerve in parotid surgeries.

BDC's Anatomy *e*-book

1. Extent of parotid gland
2. Further reading
3. Viva voce questions

Chapter

6



Temporal and Infratemporal Regions

Temporal and infratemporal regions include the following:

1. Muscles of mastication
2. Mandibular branch of trigeminal nerve
3. Temporomandibular joint (TMJ) that allows movements during speech and mastication
4. Otic ganglion
5. Maxillary artery.

Competency:
AN33.1 Describe and demonstrate extent, boundaries and contents of temporal and infratemporal fossae.

TEMPORAL FOSSA

In order to understand these regions, the osteology of the temporal fossa and the infratemporal fossa should be studied. The *temporal fossa* lies on the side of the skull and is bounded by the superior temporal line and the zygomatic arch.

Boundaries (Plate 6.1)

Anterior:	Zygomatic and frontal bones
Posterior:	Inferior temporal line and supramastoid crest
Superior:	Superior temporal line
Inferior:	Zygomatic arch (zygoma)
Inferomedial:	It communicates with infratemporal fossa
Floor:	Parts of frontal, parietal, temporal and greater wing of sphenoid
Lateral:	Temporal fascia

Contents

1. Temporalis muscle
2. Middle temporal artery (branch of superficial temporal artery)
3. Zygomaticotemporal nerve and artery
4. Deep temporal nerves for supplying temporalis muscle
5. Deep temporal artery, branch of maxillary artery

INFRATEMPORAL FOSSA

It is an irregular space under the base of the skull, below the level of zygomatic arch.

Boundaries (Plate 6.2)

Anterior:	Posterior surface of body of maxilla
Posterior:	Styloid process
Roof:	Infratemporal surface of greater wing of sphenoid
Medial:	Lateral pterygoid plate and pyramidal process of palatine bone, pterygomaxillary fissure with mandibular canal.
Lateral:	Ramus of mandible.

Communications (Fig. 6.1)

The communications of the infratemporal fossa are as follows:

Superiorly:

1. Foramen ovale—to communicate with cranial cavity
2. Foramen spinosum—to communicate with cranial cavity
3. Gap deep to the zygomatic arch—to communicate with temporal fossa.

Inferiorly:	Opens and continues with parapharyngeal space
Anteriorly:	Inferior orbital fissure—to communicate with orbit
Medially:	Pterygomaxillary fissure—to communicate with pterygopalatine fossa

Major Contents

1. *Muscles*: Lateral pterygoid, medial pterygoid and tendon of temporalis
2. *Blood vessels*: Maxillary artery, maxillary vein and pterygoid venous plexus
3. *Nerves*:
   - Mandibular nerve and its branches
   - Chorda tympani nerve (branch of facial nerve)
   - Otic ganglion
4. Sphenomandibular ligament.

Plate 6.1: Boundaries of temporal fossa

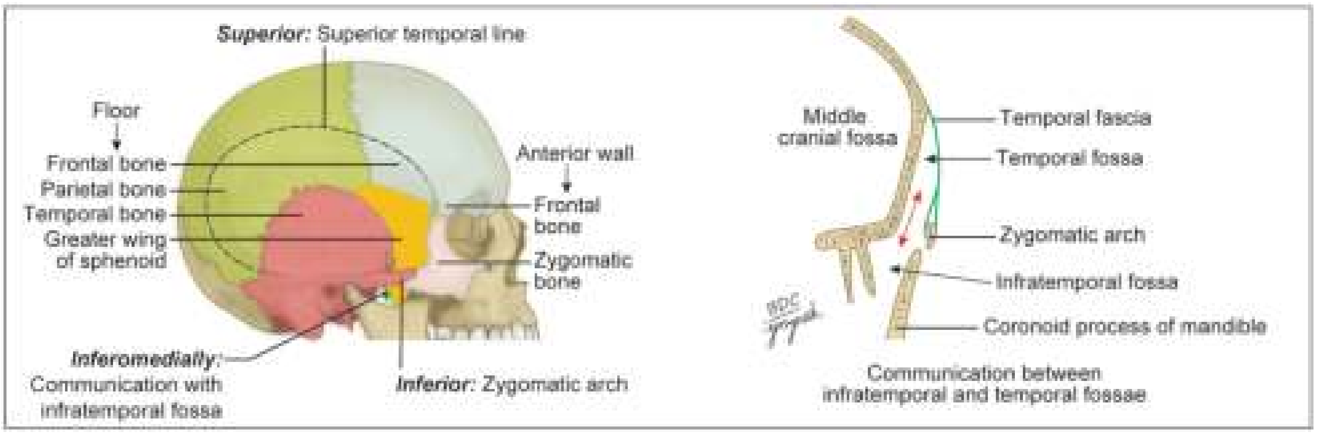
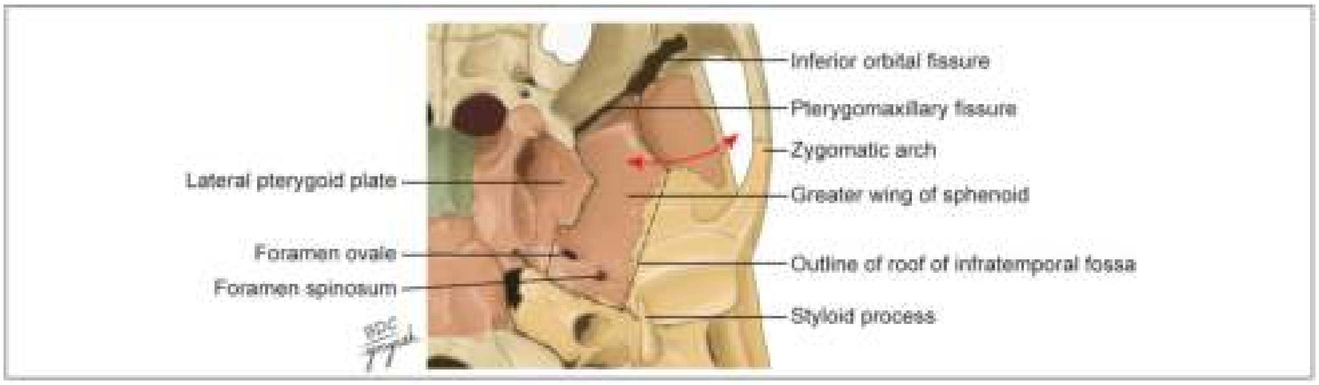

Superior: Superior temporal line
Floor
Frontal bone
Parietal bone
Temporal bone
Greater wing of sphenoid
Anterior wall
Frontal bone
Zygomatic bone
Inferomedially: Communication with infratemporal fossa
Inferior: Zygomatic arch
Middle cranial fossa
Temporal fascia
Temporal fossa
Zygomatic arch
Infratemporal fossa
Coronoid process of mandible
Communication between infratemporal and temporal fossae

Plate 6.2: Location of infratemporal fossa (inferior view)


Inferior orbital fissure
Pterygomaxillary fissure
Zygomatic arch
Greater wing of sphenoid
Lateral pterygoid plate
Foramen ovale
Foramen spinosum
Outline of roof of infratemporal fossa
Styloid process

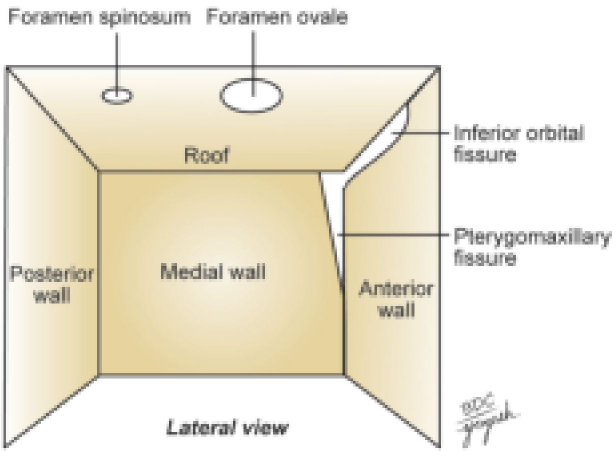

Foramen spinosum
Foramen ovale
Roof
Inferior orbital fissure
Pterygomaxillary fissure
Posterior wall
Medial wall
Anterior wall
Lateral view

Fig. 6.1: Communications of infratemporal fossa

TEMPORAL FASCIA

The temporal fascia is a thick aponeurotic sheet that roofs over the temporal fossa and covers the temporalis muscle. The fascia is extremely dense. In some species (e.g. tortoise), the temporal fascia is replaced by bone.

Attachments

1. *Superiorly*, the fascia is single layered and is attached to the superior temporal line.
2. *Inferiorly*, it splits into two layers which are attached to the inner and outer lips of the upper border of the zygomatic arch. The small gap between the two layers contains fat, a branch from the superficial temporal artery and the zygomaticotemporal nerve.

Surfaces

1. The *superficial surface* of the temporal fascia receives an expansion from the epicranial aponeurosis. This surface gives origin to the auricularis anterior and superior and is related to the superficial temporal vessels, the auriculotemporal nerve, and the temporal branch of the facial nerve.
2. The *deep surface* of the temporal fascia gives origin to some fibres of the temporalis muscle.

Competency:

AN33.2 Describe and demonstrate attachments, direction of fibres, nerve supply and actions of muscles of mastication.

MUSCLES OF MASTICATION

The principal muscles of the mastication are as follows (Table 6.1, Plate 6.3, Figs 6.2 to 6.5):

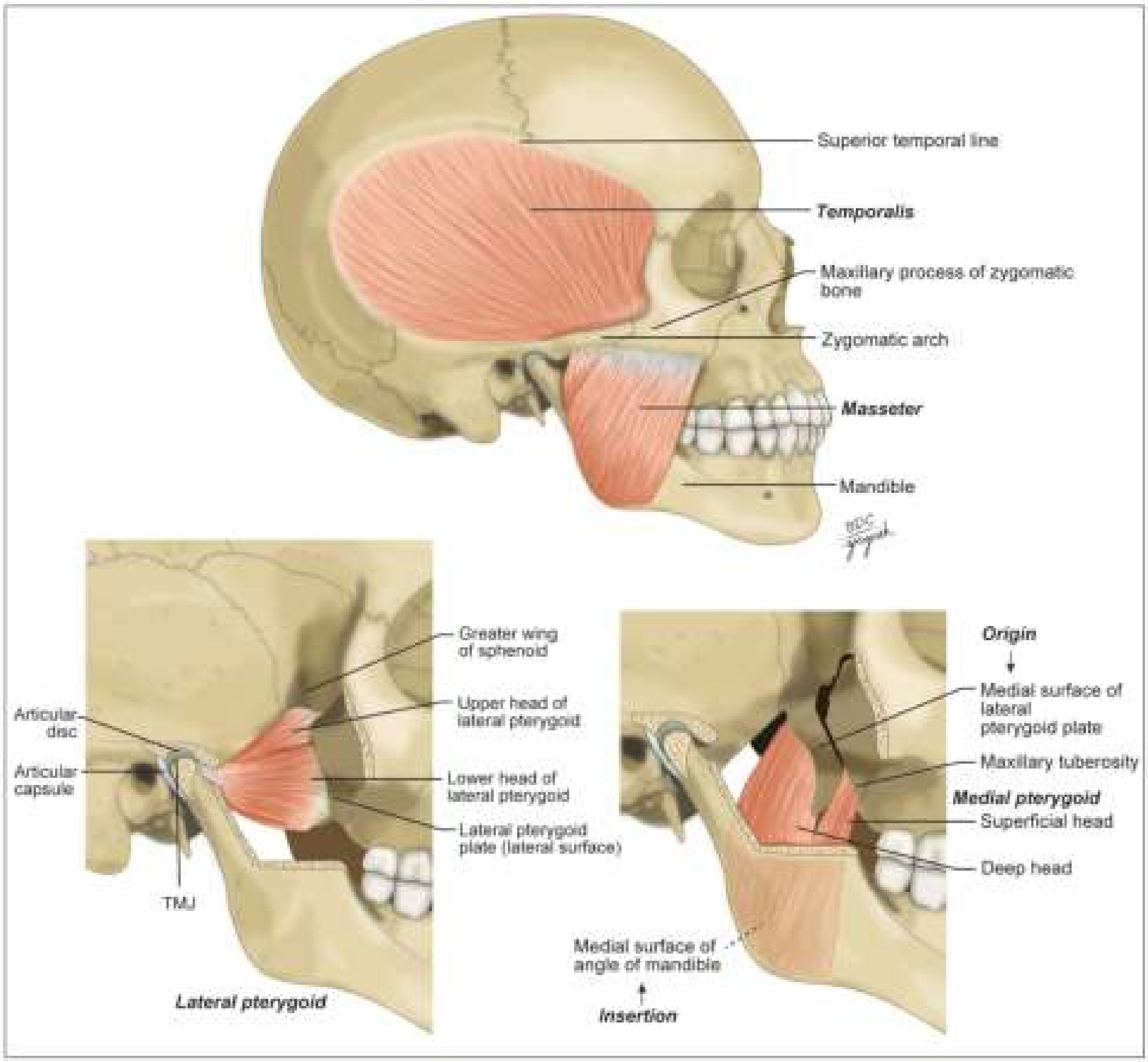
1. Masseter
2. Temporalis
3. Lateral pterygoid
4. Medial pterygoid.

TABLE 6.1: Major muscles of mastication (Figs 6.2 to 6.5)

Muscle	*Origin*	*Fibres*	*Insertion*	*Nerve supply*	*Actions*
1. **Masseter** Quadrilateral, covers lateral surface of ramus of mandible has three layers (Fig. 6.3)	**Zygomatic arch maxillary process of the zygomatic bone** a. *Superficial layer* (largest): From anterior 2/3rd of lower border of zygomatic arch and adjoining zygomatic process of maxilla b. *Middle layer:* From lower border of posterior 1/3rd of zygomatic arch c. *Deep layer:* From deep surface of zygomatic arch	a. Superficial fibres pass downwards and backwards at 45° b. Middle fibres pass vertically downwards c. Deep fibres pass vertically downwards	**Lateral surface of ramus of mandible** a. *Superficial layer* into the lower part of the lateral surface of ramus of mandible b. *Middle layer* into the central part of ramus of the mandible c. *Deep layer* into rest of the ramus of the mandible	Masseteric nerve, a branch of anterior division of mandibular nerve	a. Elevates mandible to close the mouth to bite b. Superficial fibres cause protrusion
2. **Temporalis** Fan-shaped, fills the temporal fossa (Fig. 6.4)	a. **Temporal fossa**, excluding zygomatic bone b. Temporal fascia	Anterior fibres run vertically, middle obliquely and posterior horizontally. All converge and pass through a gap deep to zygomatic arch	a. Margins and deep surface of **coronoid process** b. Anterior border of **ramus of the mandible**	Two deep temporal branches from anterior division of mandibular nerve	a. Elevates mandible b. Helps in side-to-side grinding movement c. Posterior fibres retract the protruded mandible
3. **Lateral pterygoid** Short, conical, has upper and lower heads (Fig. 6.5)	a. ***Upper head*** (small): From infratemporal surface and crest of greater wing of sphenoid bone b. ***Lower head*** (larger): From lateral surface of lateral pterygoid plate. Origin is medial to insertion	Fibres run backwards and laterally and converge for insertion	a. **Pterygoid fovea** on the anterior surface of neck of mandible b. Anterior margin of articular disc and capsule of temporomandibular joint. Insertion is posterolateral and at a slightly higher level than origin	A branch from anterior division of mandibular nerve	a. Depress mandible to open mouth, with suprahyoid muscles. It is indispensable for actively opening the mouth b. Protrudes mandible c. Right lateral pterygoid turns the chin to left side
4. **Medial pterygoid** Quadrilateral, has a small superficial and a large deep head (Fig. 6.5)	a. ***Superficial head*** (small slip): From tuberosity of maxilla and adjoining bone b. ***Deep head*** (quite large): From medial surface of lateral pterygoid plate and adjoining process of palatine bone	Fibres run downwards, backwards and laterally. The two heads embrace part of the lower head of lateral pterygoid (Fig. 6.5)	Roughened area on the medial surface of angle and adjoining **ramus of mandible**, below and behind the mandibular foramen and mylohyoid groove	Nerve to medial pterygoid, branch of the main trunk of mandibular nerve	a. Elevates mandible b. Helps protrude mandible c. Right medial pterygoid with right lateral pterygoid turn the chin to left side as part of grinding movements

[*Mnemonics:* ***Function of Lateral (La) vs. Medial (Me) pterygoid muscles:*** **"La"**: Jaw is open, so lateral pterygoid opens mouth. **"Me"**: Jaw is closed, so medial pterygoid closes the mouth]

Plate 6.3: Muscles of mastication


Superior temporal line
Temporalis
Maxillary process of zygomatic bone
Zygomatic arch
Masseter
Mandible
Greater wing of sphenoid
Upper head of lateral pterygoid
Articular disc
Articular capsule
Lower head of lateral pterygoid
Lateral pterygoid plate (lateral surface)
TMJ
Lateral pterygoid
Origin
Medial surface of lateral pterygoid plate
Maxillary tuberosity
Medial pterygoid
Superficial head
Deep head
Medial surface of angle of mandible
Insertion

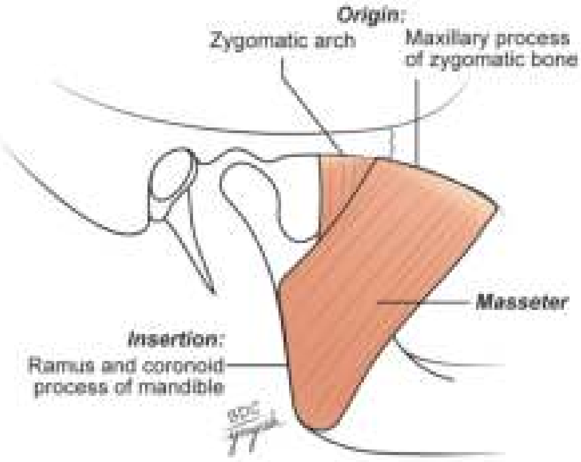

Origin:
Zygomatic arch
Maxillary process of zygomatic bone
Masseter
Insertion:
Ramus and coronoid process of mandible

Fig. 6.2: Origin and insertion of the masseter muscle

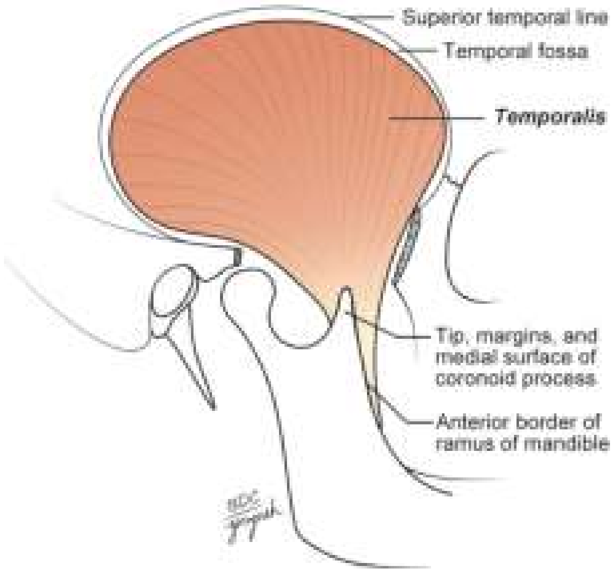

Superior temporal line
Temporal fossa
Temporalis
Tip, margins, and medial surface of coronoid process
Anterior border of ramus of mandible

Fig. 6.3: Origin and insertion of the temporalis muscle

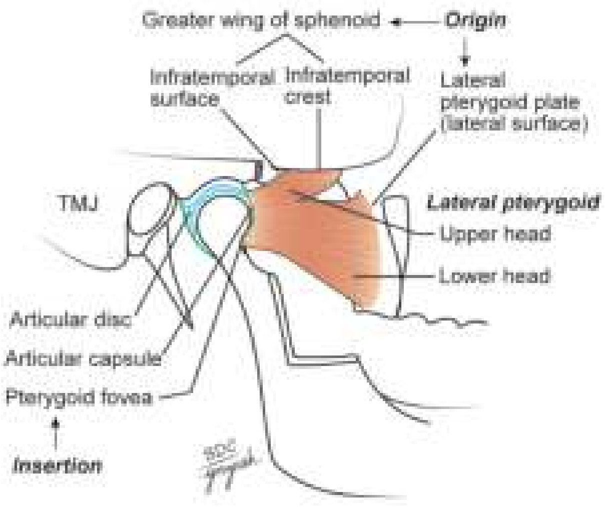

Greater wing of sphenoid
Origin
Infratemporal surface
Infratemporal crest
Lateral pterygoid plate (lateral surface)
TMJ
Lateral pterygoid
Upper head
Lower head
Articular disc
Articular capsule
Pterygoid fovea
Insertion
SDC

Fig. 6.4: Origin and insertion of the lateral pterygoid muscle (TMJ: Temporomandibular joint)

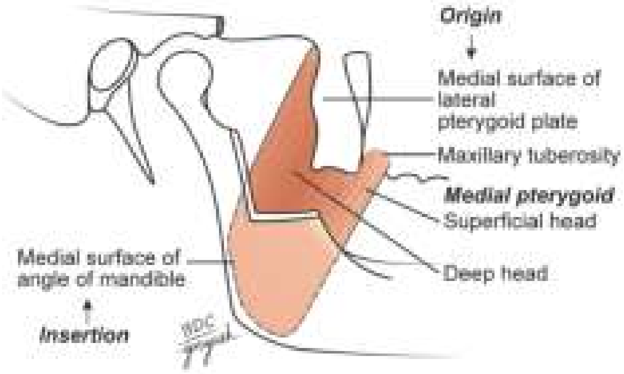

Origin
Medial surface of lateral pterygoid plate
Maxillary tuberosity
Medial pterygoid
Superficial head
Deep head
Medial surface of angle of mandible
Insertion
SDC

Fig. 6.5: Origin and insertion of the medial pterygoid muscle

Peculiarities

1. They move the mandible during mastication and speech.
2. These develop from the mesoderm of the 1st branchial arch.
3. They are supplied by the mandibular nerve which is the nerve of the 1st arch.

CLINICAL ANATOMY

Temporalis and masseter muscles are palpated by requesting the person to clench the teeth. Medial and lateral pterygoid muscles can be tested by requesting the person to move the lower jaw from one side to other side.

RELATIONS OF LATERAL PTERYGOID

The lateral pterygoid may be regarded as the key muscle of this region because its relations provide a fair idea about the layout of structures in the infratemporal fossa (Fig. 6.6, Flowchart 6.1). The relations are as follows:

Superficial Relations

1. Masseter
2. Ramus of the mandible
3. Tendon of the temporalis
4. Maxillary artery (Fig. 6.6).

Deep Relations

1. Mandibular nerve
2. Middle meningeal artery (Fig. 6.6)
3. Sphenomandibular ligament
4. Deep head of the medial pterygoid

Structures Emerging at the Upper Border

1. Deep temporal nerves (Fig. 6.6)
2. Masseteric nerve

Structures Emerging at the Lower Border

1. Lingual nerve
2. Inferior alveolar nerve and artery
3. Middle meningeal and accessory meningeal arteries pass upwards deep to it (Fig. 6.6).

Structures Passing through the Gap Between the Two Heads

1. The maxillary artery enters the gap
2. The buccal branch of the mandibular nerve with buccal artery comes out through the gap (Fig. 6.6). The pterygoid plexus of veins surrounds the lateral pterygoid.

RELATIONS OF MEDIAL PTERYGOID

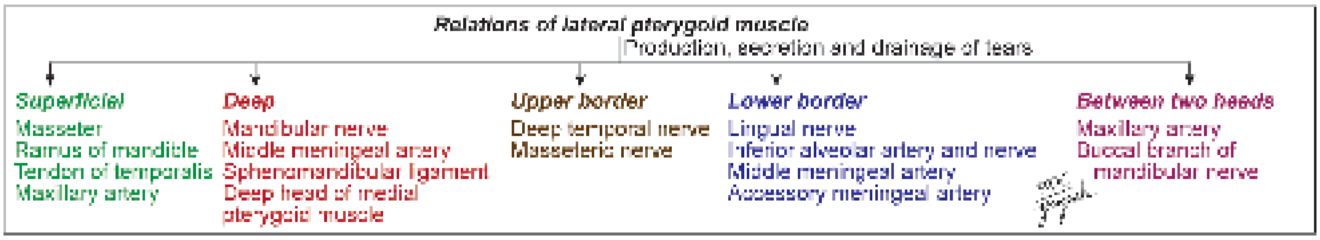
The superficial and deep heads of medial pterygoid enclose the lower head of lateral pterygoid muscle.

Superficial Relations (Fig. 6.7)

The upper part of the muscle is separated from the lateral pterygoid muscle by:

1. Lateral pterygoid plate
2. Lingual nerve
3. Inferior alveolar nerve.

Flowchart 6.1: Relations of lateral pterygoid muscle


Relations of lateral pterygoid muscle
Production, secretion and drainage of tears
Superficial
Masseter
Ramus of mandible
Tendon of temporalis
Maxillary artery
Deep
Mandibular nerve
Middle meningeal artery
Sphenomandibular ligament
Deep head of medial pterygoid muscle
Upper border
Deep temporal nerve
Masseteric nerve
Lower border
Lingual nerve
Inferior alveolar artery and nerve
Middle meningeal artery
Accessory meningeal artery
Between two heads
Maxillary artery
Buccal branch of mandibular nerve

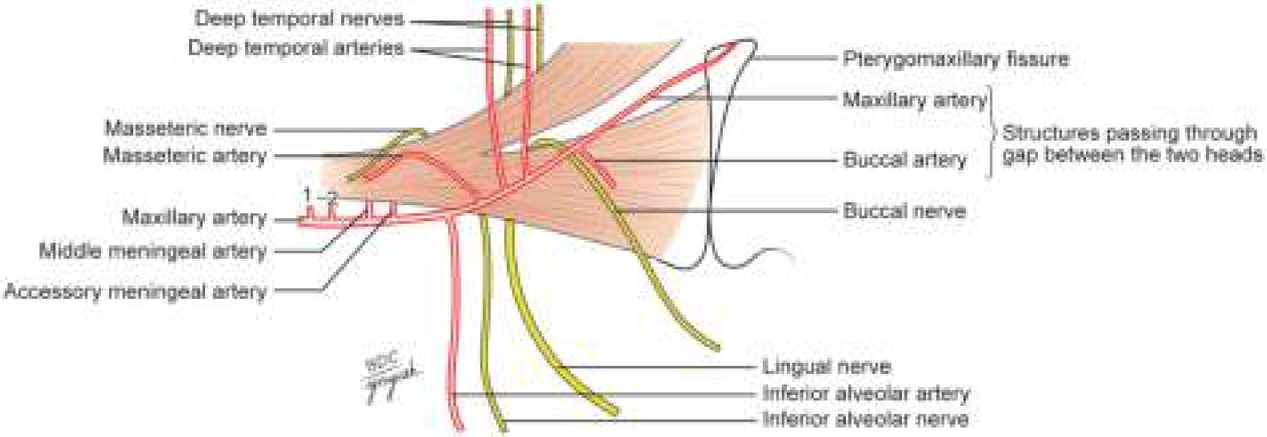

Deep temporal nerves
Deep temporal arteries
Masseteric nerve
Masseteric artery
1
2
Maxillary artery
Middle meningeal artery
Accessory meningeal artery
Pterygomaxillary fissure
Maxillary artery
Buccal artery
Structures passing through gap between the two heads
Buccal nerve
Lingual nerve
Inferior alveolar artery
Inferior alveolar nerve
BDC

Fig. 6.6: Some relations of the lateral pterygoid muscle and branches of maxillary artery

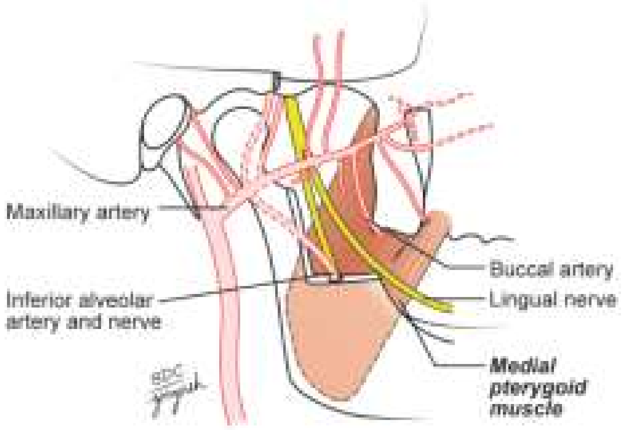

Maxillary artery
Inferior alveolar artery and nerve
Buccal artery
Lingual nerve
Medial pterygoid muscle
BDC

Fig. 6.7: Superficial relations of the medial pterygoid muscle

Lower down the muscle is separated from the ramus of the mandible by the lingual and inferior alveolar nerves, the maxillary artery, and the sphenomandibular ligament.

Deep Relations

The relations are:
1. Tensor veli palatini
2. Superior constrictor of pharynx
3. Styloglossus
4. Stylopharyngeus attached to the styloid process.

DISSECTION

Identify the masseter muscle extending from the zygomatic arch to the ramus of the mandible (Plate 6.3). Cut the zygomatic arch in front of and behind the attachment of masseter muscle and reflect it downwards. Divide the nerve and blood vessels to the muscle. Clean the ramus of mandible by stripping off the masseter muscle from it.

Give an oblique cut from the centre of mandibular notch to the lower end of anterior border of ramus of mandible. Turn this part of the bone including the insertion of temporalis muscle upwards. Strip the muscle from the skull and identify deep temporal nerves and vessels.

Make one cut through the neck of the mandible. Give another cut through the ramus at a distance of 4 cm from the neck. Remove the bone carefully in between these two cuts, avoiding injury to the underlying structures. The lateral pterygoid is exposed in the upper part and medial pterygoid in the lower part of the dissection (Fig. 6.5).

MAXILLARY ARTERY

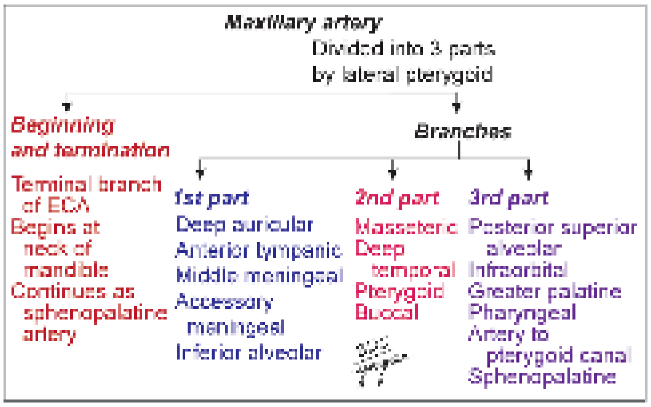
This is the larger terminal branch of the external carotid artery, given off behind the neck of the mandible.

Course and Relations

The maxillary artery is divided into three parts (Fig. 6.8, Flowchart 6.2 and Table 6.2).

1. **First (mandibular) part** runs horizontally forwards, first between the neck of the mandible and the sphenomandibular ligament, below the auriculotemporal nerve, and then along the lower border of the lateral pterygoid.
2. **Second (pterygoid) part** runs upwards and forwards superficial to the lower head of the lateral pterygoid.
3. **Third (pterygopalatine) part** passes between the two heads of the lateral pterygoid and through the pterygomaxillary fissure, to enter the pterygopalatine fossa.

Flowchart 6.2: Maxillary artery


Maxillary artery
Divided into 3 parts by lateral pterygoid
Beginning and termination
Terminal branch of ECA
Begins at neck of mandible
Continues as sphenopalatine artery
Branches
1st part
Deep auricular
Anterior tympanic
Middle meningeal
Accessory meningeal
Inferior alveolar
2nd part
Masseteric
Deep temporal
Pterygoid
Buccal
3rd part
Posterior superior alveolar
Infraorbital
Greater palatine
Pharyngeal
Artery to pterygoid canal
Sphenopalatine

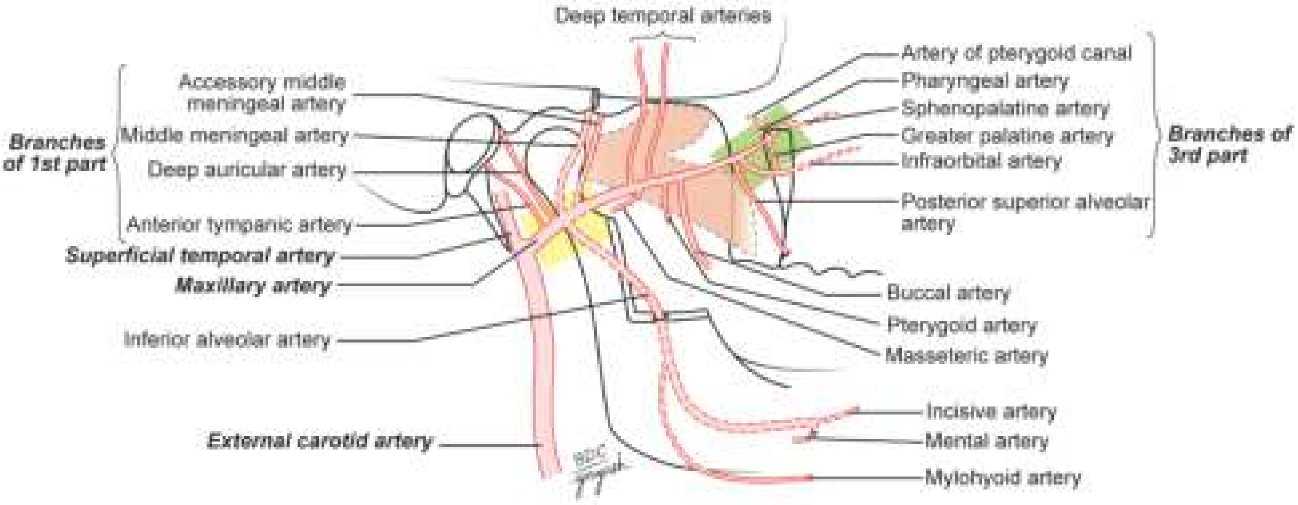

Deep temporal arteries
Accessory middle meningeal artery
Middle meningeal artery
Deep auricular artery
Branches of 1st part
Anterior tympanic artery
Superficial temporal artery
Maxillary artery
Inferior alveolar artery
External carotid artery
Artery of pterygoid canal
Pharyngeal artery
Sphenopalatine artery
Greater palatine artery
Infraorbital artery
Branches of 3rd part
Posterior superior alveolar artery
Buccal artery
Pterygoid artery
Masseteric artery
Incisive artery
Mental artery
Mylohyoid artery

Fig. 6.8: Branches of three parts of the maxillary artery

Branches

From the first part

1. Deep auricular
2. Anterior tympanic
3. Middle meningeal
4. Accessory meningeal
5. Inferior alveolar.

From the second part

1. Masseteric
2. Deep temporal
3. Pterygoid
4. Buccal.

From third part

1. Posterior superior alveolar
2. Infraorbital
3. Greater palatine
4. Pharyngeal
5. Artery to pterygoid canal
6. Sphenopalatine (terminal branch or continuation).

CLINICAL ANATOMY

- The anterior branch of middle meningeal artery is likely to be injured at the pterion in roadside accidents. It leads to ***extradural haemorrhage*** (*see* Fig. 1.9). The clot must be sucked out at the earliest, otherwise it may compress the motor area of brain.
- Bleeding from lower teeth is from branches of inferior alveolar artery (1st part of maxillary artery) and from upper teeth is from branches of 3rd part of maxillary artery. These are posterior-superior alveolar and infraorbital arteries.
- Sphenopalatine is the terminal branch of 3rd part of maxillary artery. It anastomoses with neighbouring vessels to form large capillary plexus called ***Kiesselbach's plexus*** at the anteroinferior angle of the nasal septum. It is a common site of bleeding from nose or ***epistaxis*** and is known as ***Little's area***. So sphenopalatine artery is called '***the artery of epistaxis***'.

Competency:
AN33.4 Explain the clinical significance of pterygoid venous plexus.

PTERYGOID PLEXUS OF VEINS

It is a plexus of veins that lies around and within the lateral pterygoid muscle. It is drained into the maxillary vein which begins at the posterior end of the plexus.

Communications

1. With the inferior ophthalmic vein through the inferior orbital fissure.
2. With the cavernous sinus through the emissary veins.
3. With the facial vein through the deep facial vein.

Significance

1. *Blood pump*: The contraction of the lateral pterygoid muscle pumps the blood from the pterygoid plexus of veins into cavernous sinus and maxillary vein.
2. *Spread of infection or emboli*: The infection or thromboemboli coming from facial vein or inferior ophthalmic vein may spread to cavernous sinus through the communications with pterygoid plexus of veins.

DISSECTION

External carotid artery divides into its two terminal branches, maxillary and superficial temporal on the anteromedial surface of the parotid gland. The maxillary artery, appears in this region. Identify some of its branches. Most important to be identified is the middle meningeal artery. Learn its course and branches given in *see* Chapter 12. Accompanying these branches are the veins and pterygoid venous plexus and the superficial content of infratemporal fossa. Remove these veins. Try to see its communication with the cavernous sinus and facial vein.

TABLE 6.2: Branches of maxillary artery (Figs 6.6 and 6.8)

Branches	***Foramina transmitting***	***Enters in***	***Distribution***
A. Of first part			
1. Deep auricular	Enters the external acoustic meatus through foramina at its floor	External acoustic meatus	Skin of external acoustic meatus, and outer surface of tympanic membrane
2. Anterior tympanic	Petrotympanic fissure	Tympanic cavity	Inner surface of tympanic membrane
3. Middle meningeal	Foramen spinosum	Middle cranial fossa	Supplies more of bone and less of meninges; also 5th and 7th nerves, middle ear and tensor tympani
4. Accessory meningeal	Foramen ovale	Middle cranial fossa	Main distribution is extracranial to pterygoids
5. Inferior alveolar	Mandibular foramen	Mandibular canal	Lower 8 teeth and mylohyoid muscle
B. Of second part			
1. Masseteric	—	—	Masseter
2. Deep temporal	—	—	Temporalis (two branches)
3. Pterygoid	—	—	Lateral and medial pterygoids
4. Buccal	—	—	Skin of the cheek
C. Of third part			
1. Posterior superior alveolar	Alveolar canals in body of maxilla	Body of maxilla	Upper molar and premolar teeth and gums; maxillary sinus
2. Infraorbital	Inferior orbital fissure	Inferior orbital groove or canal	Lower orbital muscles; lacrimal sac; maxillary sinus; upper incisor and canine teeth
3. Greater palatine	Greater palatine canal	Greater palatine canal to hard palate	Soft palate; tonsil; palatine glands and mucosa of upper gums
4. Pharyngeal	Pharyngeal (palatinovaginal) canal	Nasopharynx	Roof of nose and pharynx; auditory tube; sphenoidal sinus
5. Artery of pterygoid canal	Pterygoid canal	Pterygoid canal	Auditory tube; upper pharynx and middle ear
6. Sphenopalatine (terminal part)	Sphenopalatine foramen	Nasal cavity	Lateral and medial walls of nose and various air sinuses (artery of epistaxis)

Note: ***Details of branches of the maxillary artery***

1. ***Deep auricular artery*** supplies the external acoustic meatus, the tympanic membrane and the temporomandibular joint.
2. ***Anterior tympanic*** **branch** supplies the middle ear including the medial surface of the tympanic membrane.
3. ***Middle meningeal artery*** lies between lateral pterygoid and sphenomandibular ligaments, then between two roots of auriculotemporal nerve, enters the skull through foramen spinosum to reach middle cranial fossa. It divides into a large frontal branch which courses towards the *pterion* and a smaller parietal branch.
4. ***Accessory meningeal artery*** enters the cranial cavity through the foramen ovale. Apart from the meninges, it supplies structures in the infratemporal fossa.
5. ***Inferior alveolar artery*** runs downwards and forwards medial to the ramus of the mandible to reach the mandibular foramen. Passing through this foramen, the artery enters the mandibular canal (within the body of the mandible) in which it runs downwards and then forwards. Before entering the mandibular canal, the artery gives off a ***lingual branch*** to the tongue; and a ***mylohyoid branch*** that descends in the mylohyoid groove (on the medial aspect of the mandible) and runs forwards above the mylohyoid muscle. Within the mandibular canal, the artery gives branches to the mandible and to the roots of each tooth attached to the bone. It also gives off a ***mental branch*** that passes through the mental foramen to supply the chin.
6. ***Posterior superior alveolar artery*** arises just before the maxillary artery enters the pterygomaxillary fissure. It descends on the posterior surface of the maxilla and gives branches that enter canals in the bone to supply the molar and premolar teeth and the maxillary air sinus.
7. ***Infraorbital artery*** also arises just before the maxillary artery enters the pterygomaxillary fissure. It enters the orbit through the *inferior orbital fissure*. It then runs forwards in relation to the floor of the orbit, first in the infraorbital groove and then in the infraorbital canal to emerge on the face through the infraorbital foramen. It gives off some ***orbital branches***, for structures in the orbit; ***middle superior alveolar branch*** for premolar teeth and the ***anterior superior alveolar*** **branches** that enter apertures in the maxilla to reach the incisor and canine teeth attached to the bone.

   After emerging on the face, the infraorbital artery gives branches to the lacrimal sac, the nose and the upper lip.
8. ***Greater palatine artery*** runs downwards in the greater palatine canal to emerge on the posterolateral part of the hard palate through the greater palatine foramen. It then runs forwards near the lateral margin of the palate to reach the incisive canal (near the midline) through which some terminal branches enter the nasal cavity. Branches of the artery supply the palate and gums. While still within the greater palatine canal, it gives off the ***lesser palatine arteries*** that emerge on the palate through the lesser palatine foramina and run backwards into the soft palate and tonsil.
9. ***Pharyngeal branch*** runs backwards through a canal related to the inferior aspect of the body of the sphenoid bone (pharyngeal or palatinovaginal canal). It supplies part of the nasopharynx, the auditory tube and the sphenoidal air sinus.
10. ***Artery of the pterygoid canal*** runs backwards in the canal of the same name and helps to supply the pharynx, the auditory tube and the tympanic cavity.
11. ***Sphenopalatine artery*** passes medially through the sphenopalatine foramen to enter the cavity of the nose. It gives off ***posterolateral nasal branches*** to the lateral wall of the nose and to the paranasal sinuses; and ***posteromedial branches*** to the nasal septum. Sphenopalatine artery is the artery of 'epistaxis'.

Competency:
AN33.3 Describe and demonstrate articulating surface, type and movements of temporomandibular joint.

TEMPOROMANDIBULAR JOINT

Type of Joint

This is a complex, bicondylar synovial joint (Fig. 6.9, Flowchart 6.3).

Articular Surfaces

Superior articular surface is formed by the following parts of the temporal bone:

1. Tubercle of root of zygoma (zygomatic arch) and its anterior root.
2. Anterior part of mandibular fossa.
3. Posterior non-articular part formed by the tympanic plate.

Inferior articular surface is formed by the head of the mandible.

The articular surfaces are covered with *fibrocartilage*. The joint cavity is divided into upper and lower parts by an intra-articular disc.

Note: Usually, the synovial joint has articular surface covered by hyaline cartilage.

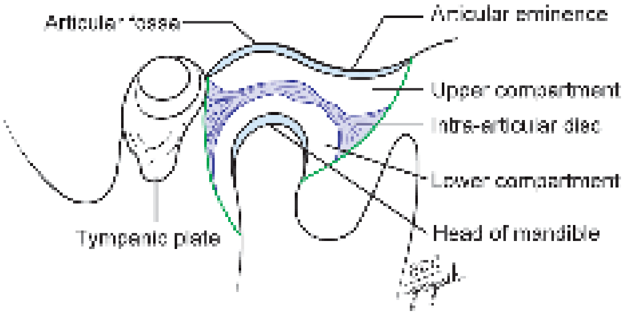

Articular fossa
Articular eminence
Upper compartment
Intra-articular disc
Lower compartment
Head of mandible
Tympanic plate

Fig. 6.9: Articular surfaces of right temporomandibular joint

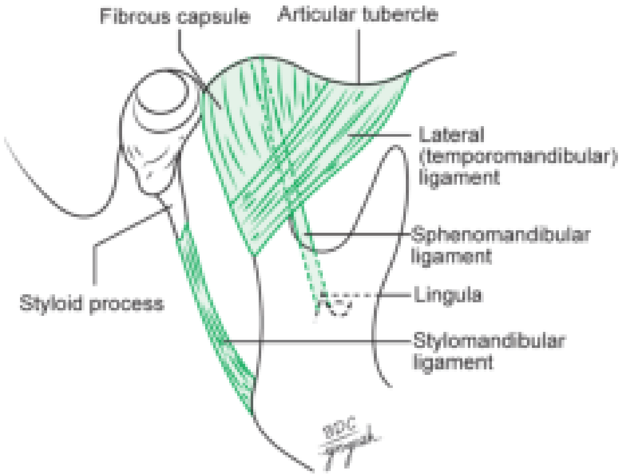
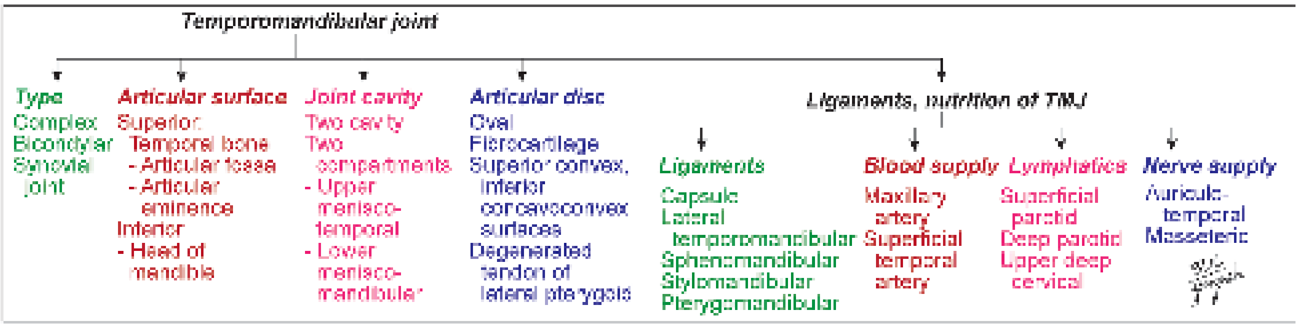

Fibrous capsule
Articular tubercle
Lateral (temporomandibular) ligament
Sphenomandibular ligament
Lingula
Styloid process
Stylomandibular ligament

Fig. 6.10: Ligaments of the temporomandibular joint

Ligaments (Fig. 6.10)

1. ***Fibrous capsule*** is attached *above* to the articular tubercle, the circumference of the mandibular fossa in front and the squamotympanic fissure behind, and *below* to the neck of the mandible. The capsule is loose above the intra-articular disc, and tight below it. The ***synovial membrane*** lines the fibrous capsule and the neck of the mandible.
2. ***Lateral temporomandibular ligament*** reinforces and strengthens the lateral part of the capsular ligament. Its fibres are directed downwards and backwards. It is attached above to the tubercle of root of zygoma and its anterior root, and below to the posterolateral aspect of the neck of the mandible.
3. ***Sphenomandibular ligament*** is an accessory ligament, that lies on a deep plane away from the fibrous capsule. It is attached superiorly to the spine of the sphenoid, and inferiorly to the lingula of the mandibular foramen. It is a remnant of the dorsal part of Meckel's cartilage.
   The ligament is related *laterally* to:
   a. Lateral pterygoid muscle
   b. Auriculotemporal nerve
   c. Maxillary artery.
   The ligament is related *medially* to:
   a. Chorda tympani nerve
   b. Wall of the pharynx.
   Near its lower end, it is pierced by the mylohyoid nerve and vessels.
4. ***Stylomandibular ligament*** is another accessory ligament of the joint. It represents a thickened part of the *deep cervical fascia* which separates the parotid and submandibular salivary glands. It is attached

Flowchart 6.3: Temporomandibular joint


Temporomandibular joint
Type
Complex
Bicondylar
Synovial joint
Articular surface
Superior
Temporal bone
- Articular fossa
- Articular eminence
Inferior
- Head of mandible
Joint cavity
Two cavity
Two compartments
- Upper menisco-temporal
- Lower menisco-mandibular
Articular disc
Oval
Fibrocartilage
Superior convex, Inferior concavoconvex surfaces
Degenerated tendon of lateral pterygoid
Ligaments, nutrition of TMJ
Ligaments
Capsule
Lateral temporomandibular
Sphenomandibular
Stylomandibular
Pterygomandibular
Blood supply
Maxillary artery
Superficial temporal artery
Lymphatics
Superficial parotid
Deep parotid
Upper deep cervical
Nerve supply
Auriculo-temporal
Masseteric

above to the lateral surface of the styloid process, and below to the angle and adjacent part of posterior border of the ramus of the mandible.

Joint Cavity and Articular Disc

The temporomandibular joint has an oval intra-articular disc. This intra-articular disc divides the joint cavity into:

1. Upper ***menisco-temporal compartment*:** It permits gliding movements.
2. Lower ***menisco-mandibular compartment*:** It permits gliding and rotational movements.

Articular Disc (Fig. 6.11)

The disc has a concavoconvex superior surface and a concave inferior surface. The periphery of the disc is attached to the fibrous capsule.

The disc is composed of an anterior region, anterior thick band, intermediate region, posterior thick band and bilaminar region containing venous plexus. The disc represents the degenerated primitive insertion of lateral pterygoid.

Functions

1. The disc prevents friction between the articulating surfaces.
2. It acts as a cushion and helps in shock absorption. It stabilises the condyle by filling up the space between articulating surfaces.
3. The proprioceptive fibres present in the disc help to regulate movements of the joint.
4. The disc helps in distribution of weight across the TMJ by increasing the area of contact.

Relations of Temporomandibular Joint (Figs 6.12 and 6.13)

Lateral

1. Skin and fasciae
2. Parotid gland
3. Temporal branches of the facial nerve.

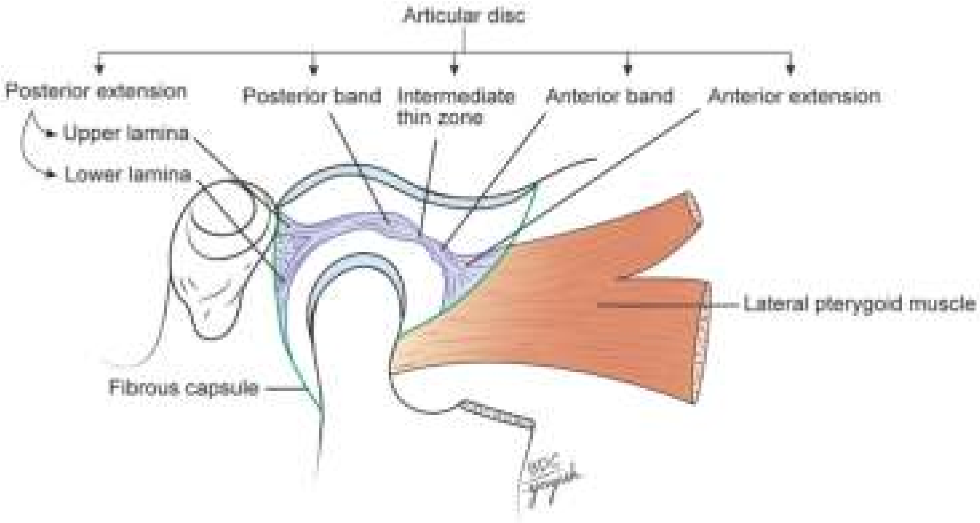

Articular disc
Posterior extension
Posterior band
Intermediate thin zone
Anterior band
Anterior extension
Upper lamina
Lower lamina
Lateral pterygoid muscle
Fibrous capsule

Fig. 6.11: Articular disc of temporomandibular joint

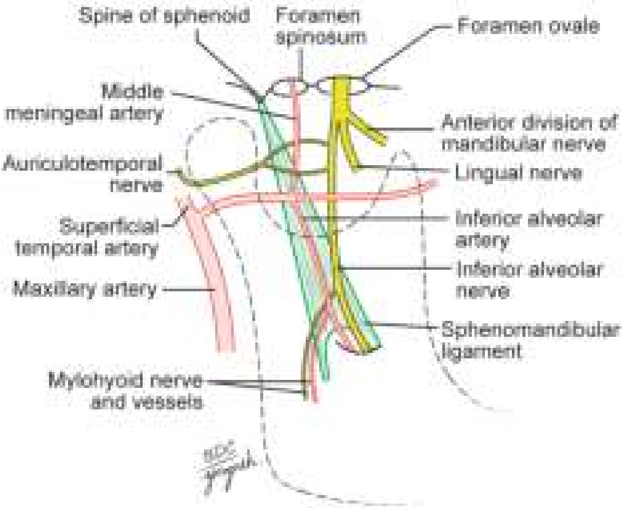

Spine of sphenoid
Foramen spinosum
Foramen ovale
Middle meningeal artery
Anterior division of mandibular nerve
Auriculotemporal nerve
Lingual nerve
Superficial temporal artery
Inferior alveolar artery
Inferior alveolar nerve
Maxillary artery
Sphenomandibular ligament
Mylohyoid nerve and vessels

Fig. 6.12: Superficial relations of the sphenomandibular ligament

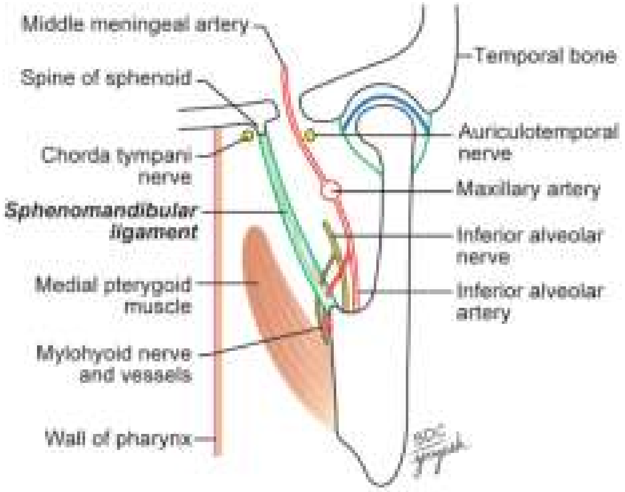

Middle meningeal artery
Temporal bone
Spine of sphenoid
Auriculotemporal nerve
Chorda tympani nerve
Maxillary artery
Sphenomandibular ligament
Inferior alveolar nerve
Medial pterygoid muscle
Inferior alveolar artery
Mylohyoid nerve and vessels
Wall of pharynx

Fig. 6.13: Superficial and deep relations of the sphenomandibular ligament (coronal section, posterior view)

Medial

1. Tympanic plate separates the joint from the internal carotid artery
2. Spine of the sphenoid, with upper end of the sphenomandibular ligament attached to it
3. Auriculotemporal and chorda tympani nerves
4. Middle meningeal artery.

Anterior

1. Lateral pterygoid
2. Masseteric nerve and artery.

Posterior

1. Parotid gland separates the joint from the external auditory meatus
2. Superficial temporal vessels
3. Auriculotemporal nerve

Superior

1. Middle cranial fossa
2. Middle meningeal vessels

Inferior

Maxillary artery and vein.

Blood Supply

Branches from superficial temporal and maxillary arteries. Veins follow the arteries.

Nerve Supply

Auriculotemporal nerve and masseteric nerve.

Movements (Figs 6.14a to d and 6.15)

1. Depression (open mouth)
2. Elevation (closed mouth)
3. Protrusion (protraction of chin)
4. Retrusion (retraction of chin)
5. Lateral or side-to-side movements during chewing or grinding.

The muscles producing these movements are listed in Table 6.3.

Mechanism of TMJ Movements

The movement of the TMJ occurs into two compartments as follows:

1. *Meniscotemporal compartment*—permits gliding movement that mostly occurs in protrusion, retraction, and chewing.
2. *Meniscomandibular compartment*—permits the rotational movement.

The ***rotational movements*** take place around two axes:

1. *Transverse axis* passing mediolaterally through the centre of neck of mandible.
2. *Vertical axis* passing through the posterior border of ramus of mandible.

Rotational movement around transverse axis takes place during depression and elevation. Rotational movement around the vertical axis takes place during side-to-side movements.

TABLE 6.3: Movements of TMJ and the responsible muscles

Movement	***Muscles and factors***
Depression	Lateral pterygoid Gravity Digastric Geniohyoid Mylohyoid
Elevation	Masseter Medial pterygoid Temporalis
Protrusion	Medial and lateral pterygoid
Retraction	Posterior fibres of temporalis
Side-by-side or chewing movements	Medial and lateral pterygoids of one side contracting alternately with that of contralateral side muscles

Depression occurs in three phases:

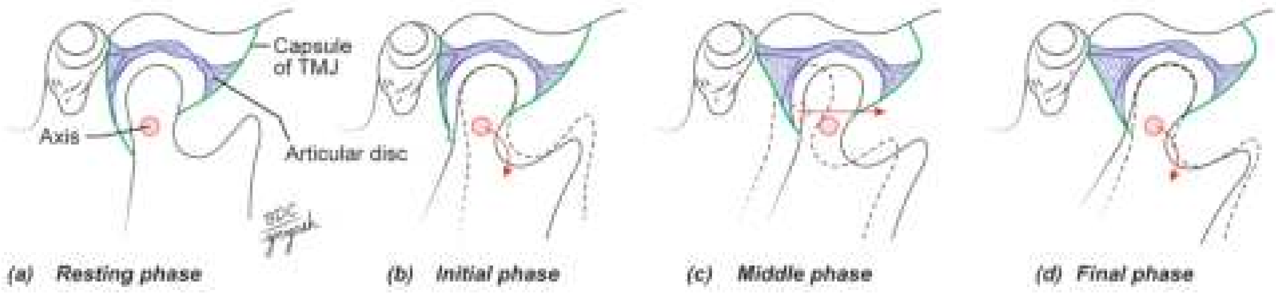
1. *Initial phase*: The depression is initiated in the lower compartment by ***forward rotation of mandibular*** head below the disc. Here, the transverse axis passing through the mandibular neck remains fixed and head moves forward and downward in the lower fixed compartments.
2. *Middle phase*: Then the movement takes place in the upper or meniscotemporal compartments by ***forward gliding of the disc*** carrying the mandibular heads with it. In this phase, the transverse axis moves itself and allows the head to move forward below the disc. Here, the disc and the head glide forward together until further movement is prevented by tension of the posterior fibres of temporalis and upper lamella of articular disc.
3. *Final phase*: In this phase, the transverse axis becomes fixed at one place and the ***head rotates around this axis*** to induce further forward and downward movements in the lower meniscotemporal compartments until the head reaches the summit of the articular tubercle.

Movement of the ***elevation*** takes place in a reverse order to that of depression.

***Side-by-side movement*:** In this movement, the mandibular head of one side glides forward in the upper meniscotemporal compartments and rotates below the disc around the vertical axis passing through the posterior border of opposite ramus of the mandible. This is followed by reverse movement and rotation of opposite head of mandible to produce side-by-side movement.

Range of mandibular movements

- Maximal depression: 50 mm
- Routine depression: 40 mm
- It includes the rotational components of 25 mm and anterior translatory gliding of 15 mm
- Maximal range of protrusion: 10 mm
- Maximal lateral movement: 10 mm


Capsule of TMJ
Axis
Articular disc
(a) Resting phase
(b) Initial phase
(c) Middle phase
(d) Final phase

Figs 6.14a to d: Movements in lower and upper compartments during opening of the mouth

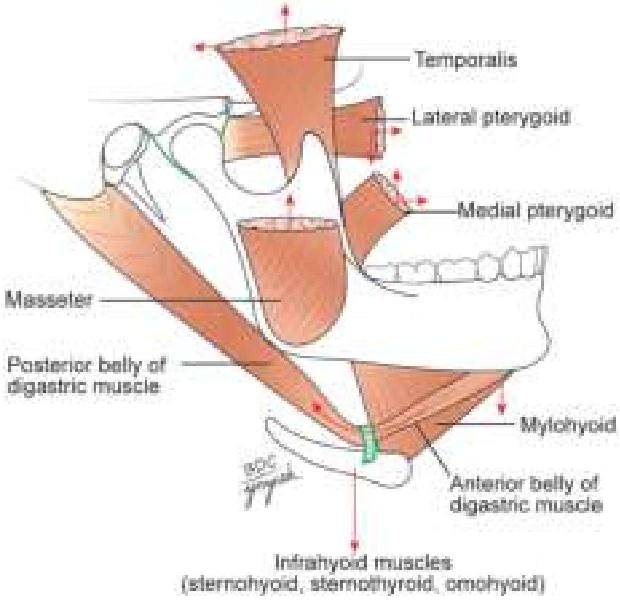

Temporalis
Lateral pterygoid
Medial pterygoid
Masseter
Posterior belly of digastric muscle
Mylohyoid
Anterior belly of digastric muscle
Infrahyoid muscles (sternohyoid, sternothyroid, omohyoid)

Fig. 6.15: Movements of temporomandibular joint (arrows) by muscles of mastication

Factors Maintaining Stability of TMJ

The TMJ is supported by the following factors that maintain the stability of TMJ:

1. *Bones*: Articular tubercles prevent the anterior dislocation and postglenoid tubercles prevent the posterior dislocation of TMJ.
2. *Ligaments*: Lateral temporomandibular ligament prevents the backward dislocation of TMJ.
3. *Muscles*: Tension of the posterior fibres of temporalis prevents the anterior dislocation and tension of lateral pterygoid prevents the posterior dislocation.
4. *Position of mandible*: The TMJ is more stable in occlusion position, that is, when the mouth is closed.

***Competency*:**
AN33.5 Describe the features of dislocation of temporomandibular joint.

CLINICAL ANATOMY

- ***Palpation of TMJ:*** To palpate the TMJ, ask the patient to open and close the mouth several times and then move the opened jaw side-by-side and finally forward and backward. During these movements, the TMJ is palpated by placing a finger into the anterior wall of outer portion of external auditory meatus, and the moving condyle of mandible can be felt. The TMJ can also be palpated by placing a finger about 1.5 cm medial to the tragus of ear.
- ***Dislocation of mandible:*** The mandible is commonly dislocated anteriorly (Fig. 6.16).
- During excessive opening of mouth, the head of mandible dislocates anteriorly as it slips forward underneath the articular eminence in the infratemporal fossa. The patient cannot close the mouth.
- ***Reduction of dislocated TMJ:*** To reduce the dislocated TMJ, the condyle of mandible must be brought back behind the articular eminence. For this, lower down the ramus of mandible by placing the thumbs on the last molar teeth and simultaneously elevating the chin with other fingers (Figs 6.17a and b).
- ***TMJ syndrome:*** The TMJ syndrome includes symptoms that are due to TMJ disorder or those that are associated with muscle involvement including fractures. These are as follows:
  1. Facial pain due to spasm of masseter
  2. Headache due to spasm of temporalis
  3. Jaw pain due to spasm of lateral pterygoid.
- ***Clicking sound at TMJ:*** The movement of TMJ may produce clicking sound or jaw popping. It may occur due to joint function or disorder such as arthritis, broken or dislocated mandibular head, muscular spasm, malocclusion of teeth and infection of parotid glands.
- Damage to VII nerve or auriculotemporal nerve may occur during TMJ surgeries (Fig. 6.18)

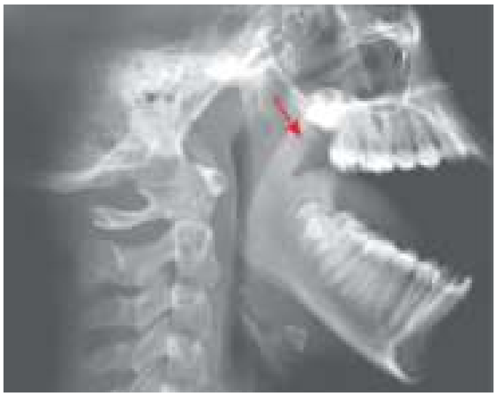
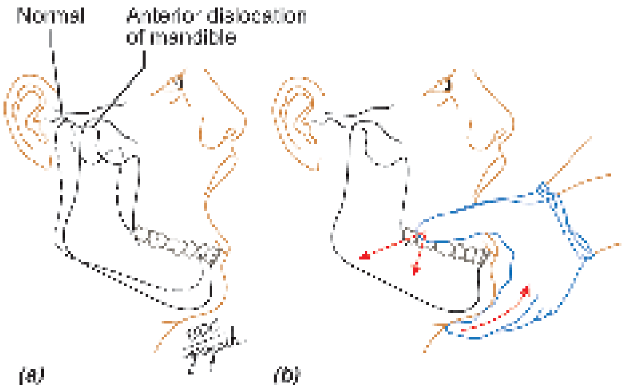


Fig. 6.16: Dislocation of the head of mandible


Normal
Anterior dislocation of mandible
(a)
(b)

Figs 6.17a and b: Dislocation of temporomandibular joint: (a) Anterior dislocation and (b) reduction of dislocated TMJ

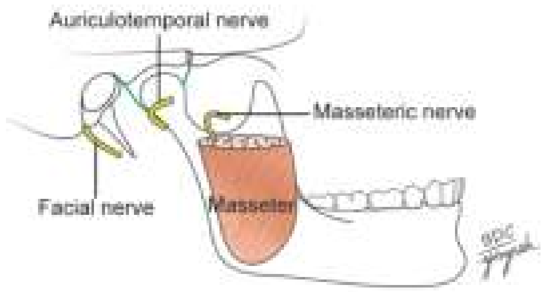

Auriculotemporal nerve
Masseteric nerve
Facial nerve
Masseter

Fig. 6.18: Nerves related to temporomandibular joint

DISSECTION

Cut the lateral pterygoid muscle close to its insertion. Dislodge the head of mandible from the articular disc. Locate the articular cartilages covering the head of the mandible and the mandibular fossa. Take out the articular disc as well and study its shape and its role in increasing the varieties of movements.

MANDIBULAR NERVE

This is the largest mixed branch of the trigeminal nerve. It is the nerve of the 1st branchial arch and supplies all structures derived from that arch. Otic and submandibular ganglia are associated with this nerve (Fig. 6.19).

Course and Relations

Mandibular nerve begins in the middle cranial fossa through a large sensory root and a small motor root. The ***sensory root*** arises from the lateral part of the trigeminal ganglion and leaves the cranial cavity through the foramen ovale.

The ***motor root*** lies deep to the trigeminal ganglion and to the sensory root. It also passes through the foramen ovale to join the sensory root just below the foramen thus forming the main trunk. The ***main trunk*** lies in the infratemporal fossa, on the tensor veli palatini, deep to the lateral pterygoid. After a short course, the main trunk divides into a small ***anterior trunk*** and a large ***posterior trunk***.

Branches (Table 6.4)

From the main trunk:

1. Meningeal branch
2. Nerve to the medial pterygoid.

From the anterior trunk:

1. A sensory branch—Buccal nerve
2. Motor branches—Masseteric and deep temporal nerves and the nerve to the lateral pterygoid.

From the posterior trunk:

1. Auriculotemporal nerve
2. Lingual nerve
3. Inferior alveolar nerve.

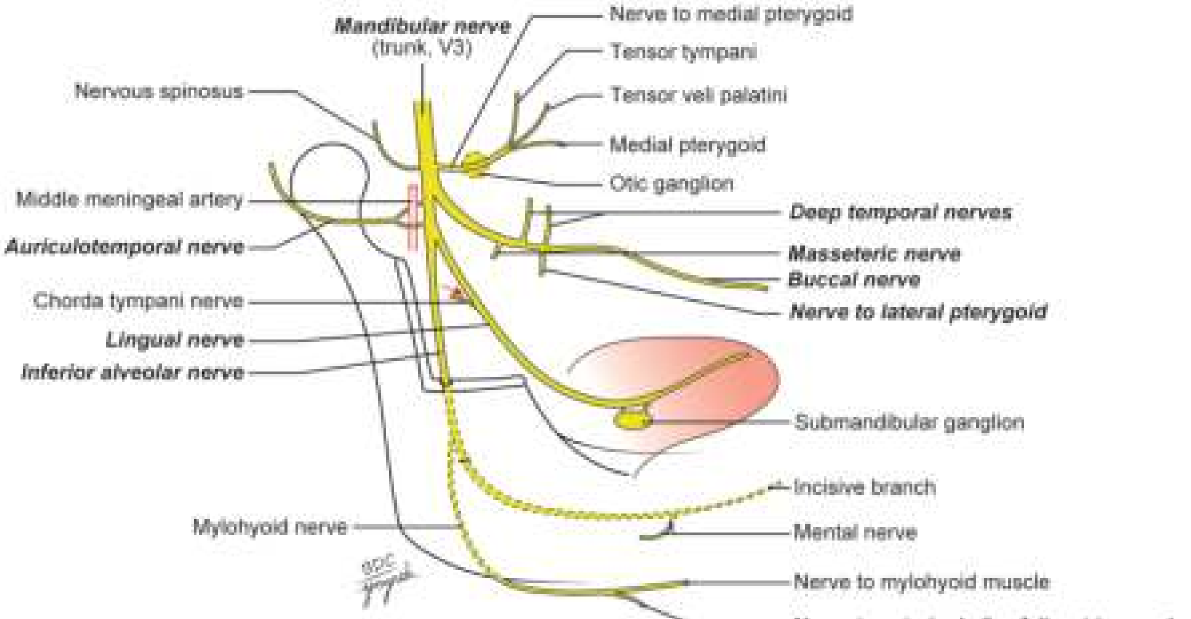

Mandibular nerve (trunk, V3)
Nervous spinosus
Middle meningeal artery
Auriculotemporal nerve
Chorda tympani nerve
Lingual nerve
Inferior alveolar nerve
Mylohyoid nerve
Nerve to medial pterygoid
Tensor tympani
Tensor veli palatini
Medial pterygoid
Otic ganglion
Deep temporal nerves
Masseteric nerve
Buccal nerve
Nerve to lateral pterygoid
Submandibular ganglion
Incisive branch
Mental nerve
Nerve to mylohyoid muscle
Nerve to anterior belly of digastric muscle

Fig. 6.19: Distribution of mandibular nerve (V3)

TABLE 6.4: Branches of the mandibular nerve (CN V3)

Muscular	*Sensory*	*Others*
Temporalis and masseter	Meningeal Auriculotemporal	Carries taste fibres
Medial and lateral pterygoids	Inferior alveolar and mental	Carries secretomotor fibres
Tensor veli palatini and tensor tympani	Lingual	Articular
Mylohyoid and digastric (anterior belly)	Buccal	—

Distribution of Mandibular Nerve

Meningeal Branch or Nervus Spinosus

Meningeal branch enters the skull through the *foramen spinosum* with the middle meningeal artery and supplies the dura mater of the middle cranial fossa.

Nerve to Medial Pterygoid

Nerve to medial pterygoid arises close to the otic ganglion and supplies the ***medial pterygoid*** from its deep surface. This nerve gives a motor root to the otic ganglion which does not relay and supplies the ***tensor veli palatini***, and the ***tensor tympani muscles***.

Buccal Nerve

Buccal nerve is the only ***sensory*** branch of the anterior division of the mandibular nerve. It passes between the two heads of the lateral pterygoid, runs downwards and forwards, and supplies the skin of cheek and mucous membrane related to the buccinator. It also supplies the labial aspect of gums of molar and premolar teeth.

Masseteric Nerve

Masseteric nerve emerges at the upper border of the lateral pterygoid just in front of the temporomandibular joint, passes laterally through the mandibular notch in company with the masseteric vessels, and enters the deep surface of the ***masseter***. It also supplies the temporomandibular joint.

Deep Temporal Nerves

Deep temporal nerves are two nerves—anterior and posterior. They pass between the skull and the lateral pterygoid and enter the deep surface of the ***temporalis***.

Nerve to Lateral Pterygoid

Nerve to lateral pterygoid enters the deep surface of the muscle.

Auriculotemporal Nerve

Auriculotemporal nerve arises by two roots that run backwards, encircle the middle meningeal artery, and unite to form a single trunk. The nerve continues backwards between the neck of the mandible and the sphenomandibular ligament, above the maxillary artery. Behind the neck of the mandible, it turns upwards and ascends on the temple behind the superficial temporal vessels.

Distribution

1. ***Auricular part*** of the nerve supplies the skin of the tragus; and the upper parts of the pinna, the external acoustic meatus and the tympanic membrane. (Note that the lower parts of these regions are supplied by the great auricular nerve and the auricular branch of the vagus nerve.)
2. ***Temporal part*** supplies the skin of the temple. *In addition,* the auriculotemporal nerve also supplies the parotid gland (secretomotor and sensory) and the temporomandibular joint.

Lingual Nerve

Lingual nerve is a branch of the posterior division of the mandibular nerve.

Course: Lingual nerve begins 1 cm below the skull. About 2 cm below skull, it is joined by chorda tympani nerve at an acute angle. Then it lies in contact with mandible medial to 3rd *molar tooth*. Finally, it lies on surface of hyoglossus and genioglossus to reach the tongue.

Relations: It begins 1 cm below the skull. It runs first between the tensor veli palatini and the lateral pterygoid, and then between the lateral and medial pterygoids.

About 2 cm below the skull, it is joined by the chorda tympani nerve.

Emerging at the lower border of the lateral pterygoid, the nerve runs downwards and forwards between the ramus of the mandible and the medial pterygoid. Next, it lies in direct contact with the mandible, medial to the third molar tooth between the origins of the superior constrictor and the mylohyoid muscles.

It soon leaves the gum and runs over the hyoglossus deep to the mylohyoid. Finally, it lies on the surface of the genioglossus deep to the mylohyoid. Here it winds around the submandibular duct and divides into its terminal branches.

Distribution: It is sensory to the anterior 2/3rd of the tongue and to the floor of the mouth. However, the fibres of the chorda tympani (branch of facial nerve) which is secretomotor to the submandibular and sublingual salivary glands and gustatory to the anterior 2/3rd of the tongue, are also distributed through the lingual nerve.

Inferior Alveolar Nerve (Fig. 6.20)

Inferior alveolar nerve is the larger terminal branch of the posterior division of the mandibular nerve. It runs vertically downwards lateral to the medial pterygoid and to the sphenomandibular ligament. It enters the mandibular foramen and runs in the mandibular canal. It is accompanied by the inferior alveolar artery.

Branches

1. The ***mylohyoid branch*** contains all the motor fibres of the posterior division. It arises just before the inferior alveolar nerve enters the mandibular foramen. It pierces the sphenomandibular ligament with the mylohyoid artery, runs in the mylohyoid groove, and supplies the ***mylohyoid*** muscle and the ***anterior belly of the digastric***.

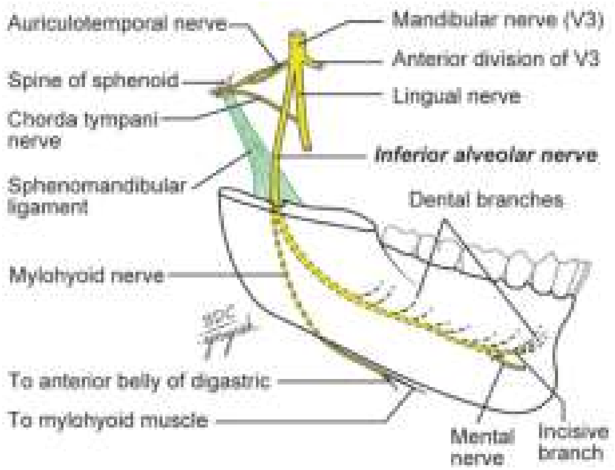


Fig. 6.20: Inferior alveolar nerve

2. While running in the mandibular canal, the inferior alveolar nerve gives branches that supply the lower teeth and gums.
3. ***Mental nerve*** emerges at the mental foramen and supplies the skin of the chin, and the skin and mucous membrane of the lower lip.
4. ***Incisive branch*** supplies the labial aspect of gums of canine and incisor teeth.

DISSECTION

Identify middle meningeal artery arising from the maxillary artery and trace it till the foramen spinosum. Note the two roots of auriculotemporal nerve surrounding the artery. Trace the origin of the auriculotemporal nerve from mandibular nerve (Fig. 6.11). Dissect all the other branches of the nerve. Identify the chorda tympani nerve joining the lingual branch of mandibular nerve. Lift the trunk of mandibular nerve laterally and locate the otic ganglion.

Trace all connections of the otic ganglion.

OTIC GANGLION

The otic ganglion is a small, oval peripheral parasympathetic ganglion (Fig. 6.21, Flowchart 6.4).

Size: 2–3 mm (pinhead)

Neurological relationship:

Topographic relation: It is connected with mandibular nerve.

Functional relation: It is related functionally to glossopharyngeal nerve.

Location: It is situated in the infratemporal fossa, immediately below the foramen ovale.

Relations

Lateral: Main trunk of mandibular nerve
Medial: Tensor veli palatini
Anterior: Middle meningeal artery
Posterior: Medial pterygoid muscle.

Roots (connections and distribution)

It has four roots as follows:

1. ***Parasympathetic or secretomotor root*:** It consists of pre- and post-ganglionic fibres:

   Preganglionic fibres begin in the inferior salivatory nucleus in the medulla and pass through glossopharyngeal and then its tympanic branch. This branch forms lesser petrosal nerve. This lesser petrosal nerve enters the middle cranial fossa and further traverses through foramen ovale. Finally, fibres from lesser petrosal nerve relay in the otic ganglion.

   Post-ganglionic fibres from the cells of otic ganglion join auriculotemporal nerve and supply the parotid gland.
2. ***Sympathetic root*:** The lateral horn cells of T1 segment of spinal cord give rise to the preganglionic sympathetic fibres. They traverse to T1 nerve, sympathetic chain, and relay in superior cervical sympathetic ganglion. Post-ganglionic fibres reach the parotid gland through a plexus around middle meningeal artery and auriculotemporal nerve. These fibres pass through the otic ganglion without relaying.
3. ***Sensory root*:** These are the fibres of auriculotemporal nerve that pass through the otic ganglion without relaying and supplying parotid gland.
4. ***Motor root*:** Fibres from the nerve to medial pterygoid pass through the otic ganglion without relay. They supply tensor veli palatini and tensor tympani muscles.

Functions

Fibres from the otic ganglion supply parotid gland as follows:

1. Parasympathetic fibres—secretomotor
2. Sympathetic fibres—vasomotor
3. Sensory fibres—carry sensation.

Note: Motor fibres supply tensor veli palatini and tensor tympani.

CLINICAL ANATOMY

- ***Frey's syndrome:*** It is a rare neurological disorder resulting in gustatory sweating (Fig. 11.11). It may result due to damage to auriculotemporal and great auricular nerves in the parotid gland injuries or surgeries. The parasympathetic fibres of auriculotemporal nerve stimulate the parotid gland to enhance its secretion and sympathetic fibres of the great auricular nerve stimulate sweat glands in the facial skin. After damage to these both nerves, during regeneration, the parasympathetic fibres of auriculotemporal nerve grow and join the sympathetic fibres of the great auricular nerve. This results in sweating rather than salivation during eating. Hence, it is called *gustatory sweating* or *Frey's syndrome*.
- ***Clinical testing of mandibular nerve:*** The motor part of the mandibular nerve is tested clinically by asking the patient to clench her/his teeth and then feeling for the contracting masseter and temporalis muscles on the two sides. If one masseter is paralysed, the jaw

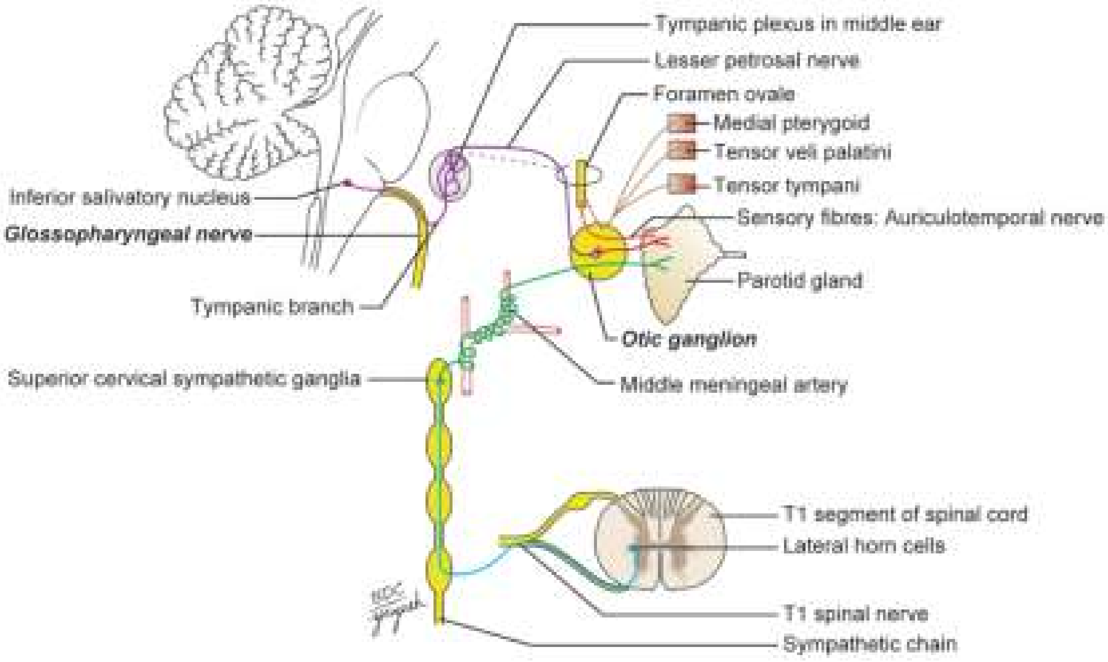
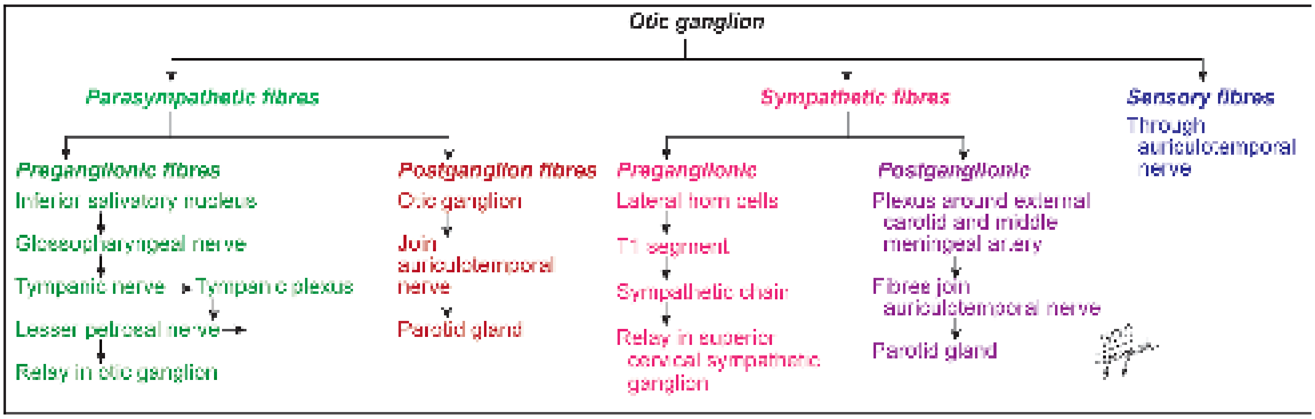

Tympanic plexus in middle ear
Lesser petrosal nerve
Foramen ovale
Medial pterygoid
Tensor veli palatini
Tensor tympani
Sensory fibres: Auriculotemporal nerve
Parotid gland
Otic ganglion
Middle meningeal artery
Inferior salivatory nucleus
Glossopharyngeal nerve
Tympanic branch
Superior cervical sympathetic ganglia
T1 segment of spinal cord
Lateral horn cells
T1 spinal nerve
Sympathetic chain

Fig. 6.21: Innervation of parotid gland (schematic representation, Purple line: Preganglionic parasympathetic fibres, Red line: Post-ganglionic parasympathetic fibres, Blue line: Preganglionic sympathetic fibres, Green line: Post-ganglionic sympathetic fibres, *Note*: Lesser petrosal nerve enter the middle cranial fossa and exit through the foramen ovale. Middle cranial fossa shown by grey dotted line)

Flowchart 6.4: Otic ganglion


Otic ganglion
Parasympathetic fibres
Sympathetic fibres
Sensory fibres
Through auriculotemporal nerve
Preganglionic fibres
Inferior salivatory nucleus
Glossopharyngeal nerve
Tympanic nerve
Tympanic plexus
Lesser petrosal nerve
Relay in otic ganglion
Postganglion fibres
Otic ganglion
Join auriculotemporal nerve
Parotid gland
Preganglionic
Lateral horn cells
T1 segment
Sympathetic chain
Relay in superior cervical sympathetic ganglion
Postganglionic
Plexus around external carotid and middle meningeal artery
Fibres join auriculotemporal nerve
Parotid gland

deviates to the paralysed side, on opening the mouth by the action of the normal lateral pterygoid of the opposite side. The activity of the pterygoid muscles is tested by asking the patient to move the chin from side-to-side.

- ***Referred pain:*** In cases with cancer of the tongue, pain radiates to the ear and to the temporal fossa, over the distribution of the auriculotemporal nerve as both lingual and auriculotemporal nerves are branches of mandibular nerve. Sometimes the lingual nerve is divided to relieve intractable pain of this kind. This may be done where the nerve lies in contact with the mandible below and behind the last molar tooth, covered only by mucous membrane.
- ***Mandibular neuralgia:*** Trigeminal neuralgia of the mandibular division is often difficult to treat. In such cases, the sensory root of the nerve may be divided behind the ganglion, and this is now the operation of choice when pain is confined to the distribution of the maxillary and mandibular nerves. During division, the ophthalmic fibres that lie in the superomedial part of the root are spared, to preserve the corneal reflex thus avoiding damage to the cornea (Fig. 6.22).
- ***Lingual nerve injury:*** Lingual nerve lies in contact with mandible, medial to the 3rd molar tooth. In extraction of malplaced 'wisdom' tooth, care must be taken not to injure the lingual nerve. Its injury results in loss of general and taste sensations from anterior two-thirds of the tongue oral mucosa, gingivae, chin and lower lip.
- ***Jaw-jerk reflex:*** The mandibular nerve supplies both the efferent and afferent loops of the jaw-jerk reflex, as it is a mixed nerve. Tapping the chin causes contraction of the pterygoid muscles. A lesion at the foramen ovale leads to paraesthesia along the mandible, tongue, temporal region and paralysis of

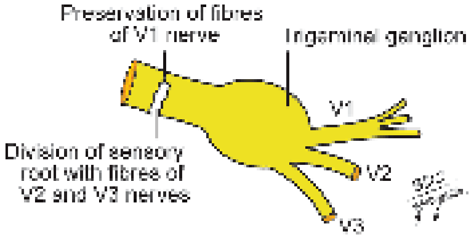

Preservation of fibres of V1 nerve
Trigeminal ganglion
V1
V2
V3
Division of sensory root with fibres of V2 and V3 nerves

Fig. 6.22: Partial cutting of the sensory root of trigeminal nerve

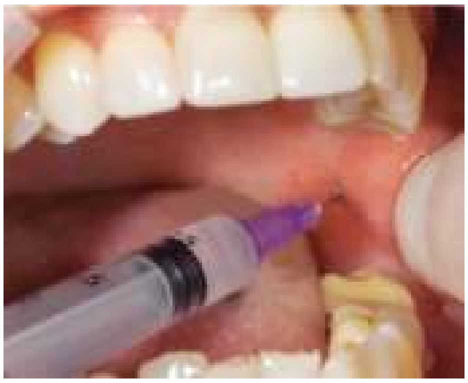


Fig. 6.23: Injection given in mandibular foramen for anaesthetising the inferior alveolar nerve before extraction of last molar tooth

the muscles of mastication. This also leads to loss of jaw-jerk reflex.

- ***Inferior alveolar nerve block:*** In extraction of mandibular teeth, inferior alveolar nerve needs to be anaesthetised. The drug is given into the nerve before it enters the mandibular canal (Fig. 6.20).
- During extraction of the 3rd molar, the buccal nerve may get involved by the local anaesthesia causing temporary numbness of the cheek (Fig. 6.23).

VIDEO

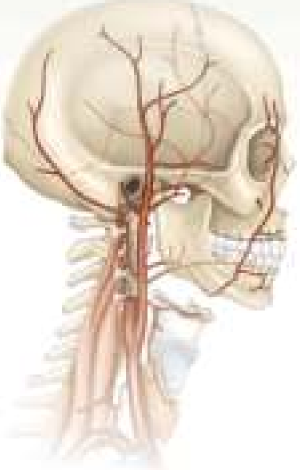
Video 3.6 Infratemporal Fossa: Muscles of mastication, Mandibular nerve

Facts to Remember

- Mandibular nerve is associated with two parasympathetic ganglia, i.e. otic and submandibular ganglia.
- Only muscle of mastication which depresses the TMJ is the lateral pterygoid muscle.
- Masseter is the chief elevator of the mandible.
- Spine of sphenoid is related to chorda tympani and auriculotemporal nerves.
- Auriculotemporal nerve and branches of facial nerve are related to temporomandibular joint.
- The most common dislocation of the TMJ is anterior.
- Inferior alveolar nerve block is given for dental procedures of the lower jaw.
- Trismus or locked jaw occurs due to spasm of both the masseters. It is typically seen in tetanus.
- The course of the maxillary artery is divided into three parts by a lateral pterygoid.
- Middle meningeal artery is encircled by two roots of auriculotemporal nerve.

BDC's Anatomy *e*-book

1. Landmarks on the lateral side of the head
2. Maxillary artery: Territory of distribution
3. Further reading
4. Viva voce questions



Chapter
7

Submandibular Region

Competency:
AN34.1 Describe and demonstrate the superficial and deep structures, muscles, nerves, vessels, and glands in the submandibular region.

Submandibular region includes deeper structures in the area between the mandible and hyoid bone, including the floor of the mouth and the root of the tongue.

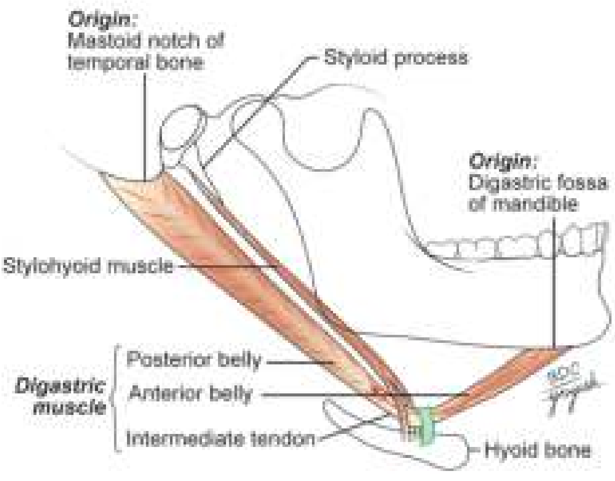
Contents of submandibular region:

1. Suprahyoid muscles
2. Submandibular and sublingual salivary glands
3. *Nerves*: Lingual, hypoglossal and glossopharyngeal nerves, and submandibular ganglion
4. *Vessels*: Lingual and facial arteries
5. Root of tongue and floor of mouth.

SUPRAHYOID MUSCLES

The suprahyoid muscles are the digastric, the stylohyoid, the mylohyoid and the geniohyoid. The muscles are in following layers (Figs 7.1 to 7.5, Tables 7.1 and 7.2, Plate 7.1):

1. *First layer*: Digastric (Greek *two bellies*) and stylohyoid
2. *Second layer*: Mylohyoid (Greek *pertaining to hyoid bone*)
3. *Third layer*: Geniohyoid and hyoglossus
4. *Fourth layer*: Genioglossus.

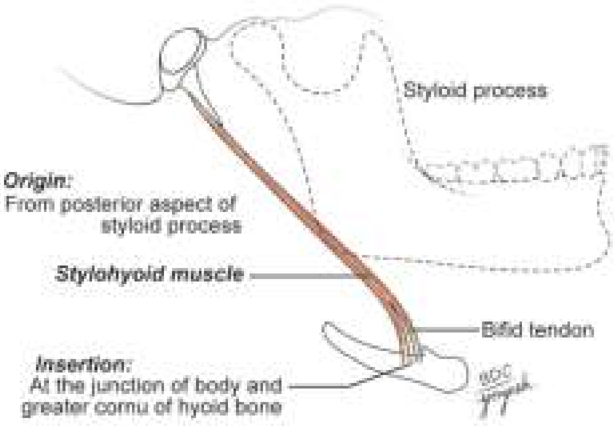


Origin:
Mastoid notch of temporal bone
Styloid process
Origin:
Digastric fossa of mandible
Stylohyoid muscle
Digastric muscle
Posterior belly
Anterior belly
Intermediate tendon
Hyoid bone

Fig. 7.1: Digastric muscle

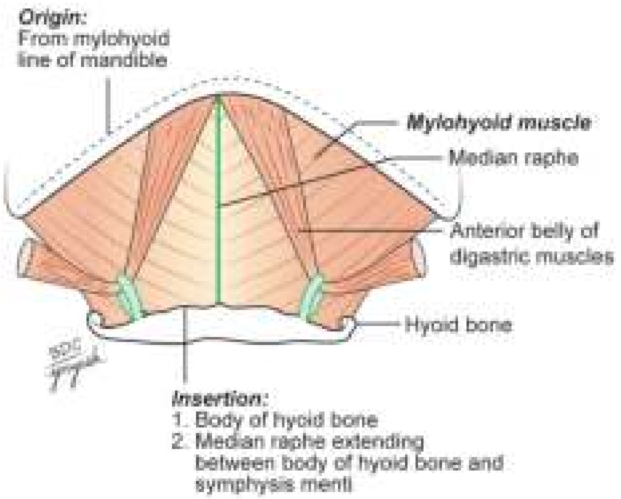
DISSECTION

Cut the facial artery and vein present at the anteroinferior angle of masseter muscle. Separate the origin of anterior belly of digastric muscle from the digastric fossa near the symphysis menti. Push the mandible upwards. Clean and expose the posterior belly of digastric muscle and its accompanying stylohyoid muscle. Identify the digastrics, stylohyoid, mylohyoid, geniohyoid and hyoglossus.



Styloid process
Origin:
From posterior aspect of styloid process
Stylohyoid muscle
Bifid tendon
Insertion:
At the junction of body and greater cornu of hyoid bone

Fig. 7.2: Stylohyoid muscle



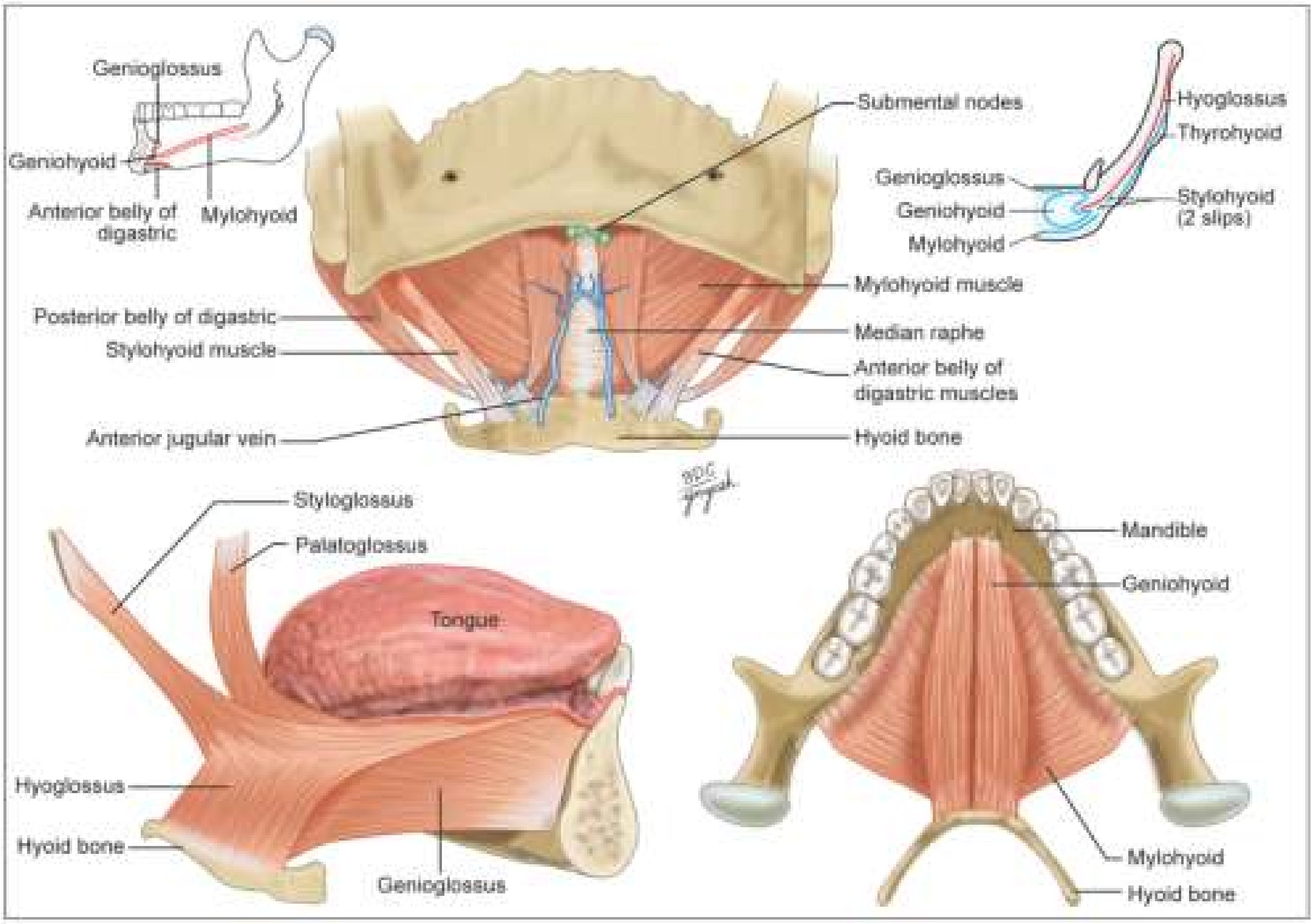
Origin:
From mylohyoid line of mandible
Mylohyoid muscle
Median raphe
Anterior belly of digastric muscles
Hyoid bone
Insertion:
1. Body of hyoid bone
2. Median raphe extending between body of hyoid bone and symphysis menti

Fig. 7.3: Mylohyoid muscle

TABLE 7.1: **Suprahyoid muscles** (Figs 7.1 to 7.5)

Muscle	*Origin*	*Fibres*	*Insertion*	*Nerve supply*	*Actions*
1. **Digastric** (DG): It has two bellies united by an intermediate tendon. Anterior belly is unipennate and posterior belly is bipennate (Table 7.2)	a. Anterior belly (DGA): From digastric fossa of **mandible** b. Posterior belly (DGP): From mastoid notch of **temporal bone**	a. Anterior belly runs downwards and backwards b. Posterior belly runs downwards and forwards	Both heads meet at the **intermediate tendon** which perforates stylohyoid and is held by a fibrous pulley to the hyoid bone	a. Anterior belly by nerve to mylohyoid (V3) b. Posterior belly by facial nerve (VII)	a. Depresses mandible when mouth is opened widely or against resistance; it is secondary to lateral pterygoid b. Elevates hyoid bone
2. **Stylohyoid** (SH): Small muscle, lies on upper border of DGP	Posterior surface of **styloid process**	Tendon is perforated by DGP tendon	Junction of body and greater cornua of **hyoid bone**	Facial nerve (VII)	a. Pulls hyoid bone upwards and backwards b. With other hyoid muscles, it fixes the hyoid bone
3. **Mylohyoid** (MH): Flat, triangular muscle; two mylohyoids form floor of mouth cavity, deep to DGA	**Mylohyoid line** of mandible	Fibres run medially and slightly downwards	a. Posterior fibres: Body of **hyoid bone** b. Middle and anterior fibres; **median raphe**, between mandible and hyoid bone	Nerve to mylohyoid (V3)	a. Elevates floor of mouth in first stage of deglutition b. Helps in depression of mandible, and elevation of hyoid bone
4. **Geniohyoid** (GH): Short and narrow muscle; lies above medial part of MH	**Inferior genial tubercle** of mandible	Runs backwards and downwards	Anterior surface of body of **hyoid bone**	C1 through hypoglossal nerve	a. Elevates hyoid bone b. May depress mandible when hyoid is fixed
5. **Hyoglossus:** It is a muscle of tongue. It forms important landmark in this region	Whole length of greater cornua and lateral part of body of **hyoid bone**	Fibres run upwards and forwards	Side of **tongue** between styloglossus and inferior longitudinal muscle of tongue	Hypoglossal (XII) nerve	Depresses tongue makes dorsum convex, retracts the protruded tongue
6. **Genioglossus:** It is the bulkiest muscle of tongue. It is fan-shaped	**Superior genial tubercle** of mandible	Fibres radiate	Upper fibres pass upwards and forwards to tip of **tongue**. Middle fibres along whole length of dorsum. Lower fibres into body of **hyoid**	Hypoglossal (XII)	Pulls posterior part of tongue forwards, i.e. protrudes tongue. It is a life-saving muscle

Plate 7.1: Suprahyoid muscles


Genioglossus
Geniohyoid
Anterior belly of digastric
Mylohyoid
Submental nodes
Hyoglossus
Thyrohyoid
Genioglossus
Geniohyoid
Mylohyoid
Stylohyoid (2 slips)
Mylohyoid muscle
Posterior belly of digastric
Stylohyoid muscle
Median raphe
Anterior belly of digastric muscles
Anterior jugular vein
Hyoid bone
Styloglossus
Palatoglossus
Tongue
Mandible
Geniohyoid
Hyoglossus
Hyoid bone
Genioglossus
Mylohyoid
Hyoid bone

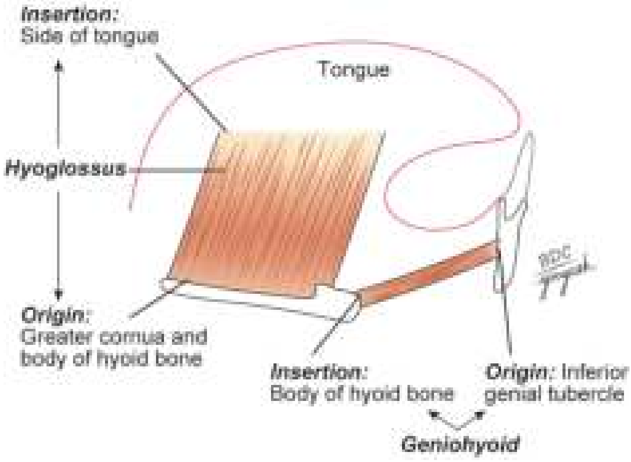

Insertion:
Side of tongue
Tongue
Hyoglossus
Origin:
Greater cornua and body of hyoid bone
Insertion:
Body of hyoid bone
Origin: Inferior genial tubercle
Geniohyoid

Fig. 7.4: Geniohyoid and hyoglossus muscles

TABLE 7.2: Differences between the anterior and posterior bellies of digastric

Feature	*Anterior belly*	*Posterior belly*
Structure	Unipennate	Bipennate
Development	1st pharyngeal arch	2nd pharyngeal arch
Innervation	Mylohyoid branch of inferior alveolar nerve (mandibular nerve)	Facial nerve

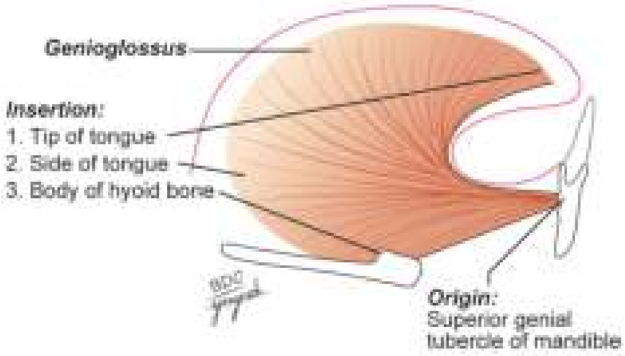

Genioglossus
Insertion:
1. Tip of tongue
2. Side of tongue
3. Body of hyoid bone
Origin:
Superior genial tubercle of mandible

Fig. 7.5: Genioglossus muscle

Relations of Posterior Belly of Digastric (Fig. 7.6)

Superficial

1. Mastoid process with the sternocleidomastoid, splenius capitis and the longissimus capitis
2. Stylohyoid
3. Parotid gland with retromandibular vein
4. Submandibular salivary gland and lymph nodes
5. Angle of the mandible with medial pterygoid

Deep

1. Transverse process of the atlas with superior oblique and the rectus capitis lateralis

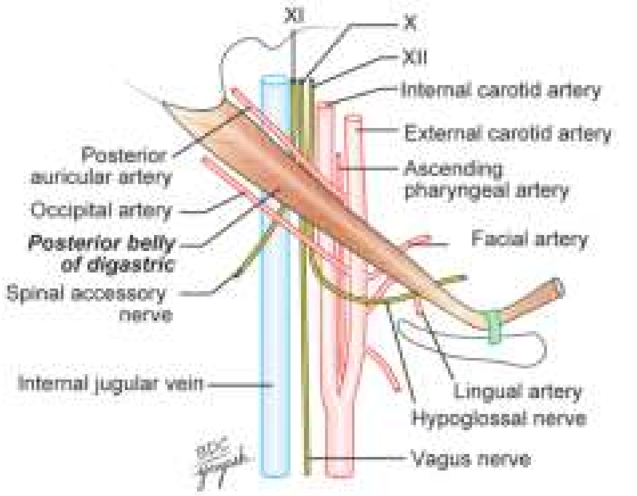

XI
X
XII
Internal carotid artery
External carotid artery
Ascending pharyngeal artery
Facial artery
Posterior auricular artery
Occipital artery
Posterior belly of digastric
Spinal accessory nerve
Internal jugular vein
Lingual artery
Hypoglossal nerve
Vagus nerve

Fig. 7.6: Relations of the posterior belly of the digastric muscle

2. Internal carotid, external carotid, lingual, facial and occipital arteries
3. Internal jugular vein
4. Vagus, accessory and hypoglossal cranial nerves
5. The hyoglossus muscle.

Upper Border

1. Posterior auricular artery
2. Stylohyoid muscle.

Lower Border

Lower border is related to occipital artery.

Relations of Mylohyoid (Fig. 7.7)

Superficial

1. Anterior belly of digastric
2. Superficial part of the submandibular salivary gland
3. Mylohyoid nerve and vessels
4. Submental branch of the facial artery.

Deep

1. Hyoglossus with its superficial relations, namely the styloglossus, the lingual nerve, the submandibular ganglion, the deep part of the submandibular salivary gland, the submandibular duct, the hypoglossal nerve and the venae comitantes hypoglossi.
2. The genioglossus with its superficial relations, namely the sublingual salivary gland, the lingual nerve, submandibular duct, the lingual artery, and the hypoglossal nerve.

Relations of Hyoglossus

Superficial

Styloglossus, lingual nerve, submandibular ganglion, deep part of the submandibular gland, submandibular duct, hypoglossal nerve and veins accompanying it.

Deep

1. Inferior longitudinal muscle of the tongue
2. Genioglossus
3. Middle constrictor of the pharynx
4. Glossopharyngeal nerve
5. Stylohyoid ligament
6. Lingual artery.

Structures passing deep to posterior border of hyoglossus from above downwards:

1. Glossopharyngeal nerve
2. Stylohyoid ligament
3. Lingual artery.

Competency:
AN34.2 Describe and demonstrate the morphology, relations and nerve supply of submandibular salivary gland and submandibular ganglion.

SUBMANDIBULAR SALIVARY GLAND

This is a large salivary gland, situated in the anterior part of the digastric triangle.

Dimensions: The gland is about the size of a walnut weighing about 15 to 20 g. It is roughly J-shaped, being indented by the posterior border of the mylohyoid which divides it into:

1. A larger superficial part that lies superficial to the muscle
2. A small deep part lying deep to the muscle (Fig. 7.8, Flowchart 7.1).

Superficial Part

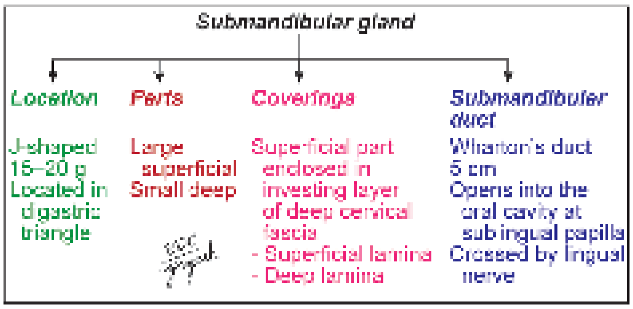
This part of the gland fills the digastric triangle. It extends superiorly deep to the mandible up to the mylohyoid line. Inferiorly: It overlaps stylohyoid and the posterior belly of digastric (Fig. 7.8). It has three surfaces:

1. Inferior
2. Lateral
3. Medial.

Coverings of Superficial Part

It is partially enclosed between two layers of deep cervical fascia. The superficial (Fig. 7.6) layer of fascia covers the inferior surface of the gland and is attached to the base of the mandible. The deep layer covers the medial surface of the gland and is superior to the mylohyoid line of the mandible (Fig. 7.9).

Flowchart 7.1: Submandibular gland


Submandibular gland
Location
Parts
Coverings
Submandibular duct
J-shaped
15–20 g
Located in digastric triangle
Large superficial
Small deep
Superficial part enclosed in investing layer of deep cervical fascia
- Superficial lamina
- Deep lamina
Wharton's duct
5 cm
Opens into the oral cavity at sublingual papilla
Crossed by lingual nerve

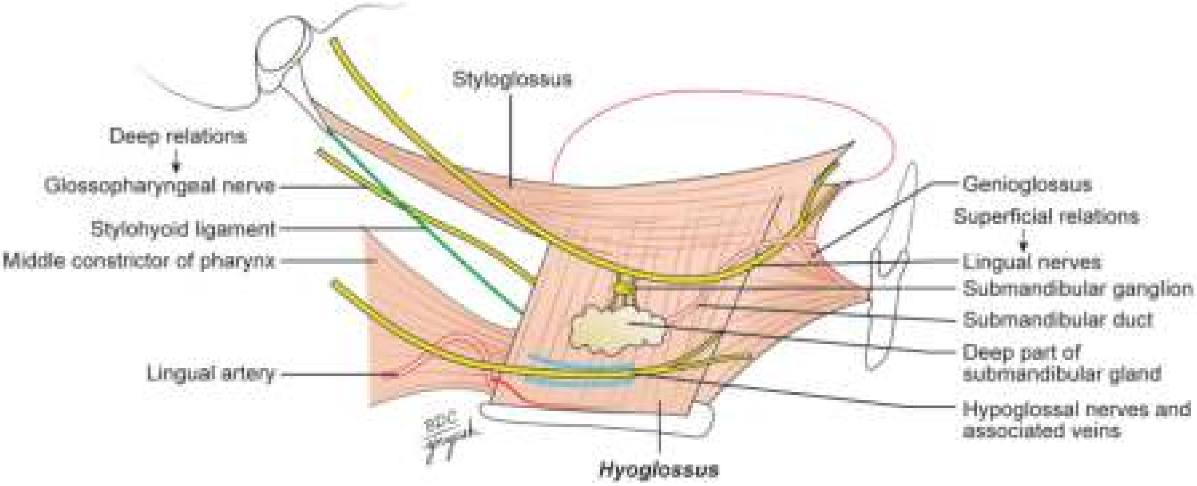

Styloglossus
Deep relations
Glossopharyngeal nerve
Stylohyoid ligament
Middle constrictor of pharynx
Lingual artery
Genioglossus
Superficial relations
Lingual nerves
Submandibular ganglion
Submandibular duct
Deep part of submandibular gland
Hypoglossal nerves and associated veins
Hyoglossus

Fig. 7.7: Relations of the hyoglossus and genioglossus muscles

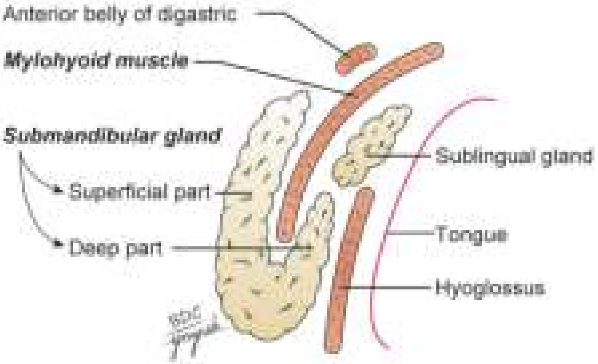

Anterior belly of digastric
Mylohyoid muscle
Submandibular gland
Superficial part
Deep part
Sublingual gland
Tongue
Hyoglossus

Fig. 7.8: Horizontal section through the submandibular region showing the location of the submandibular and sublingual glands

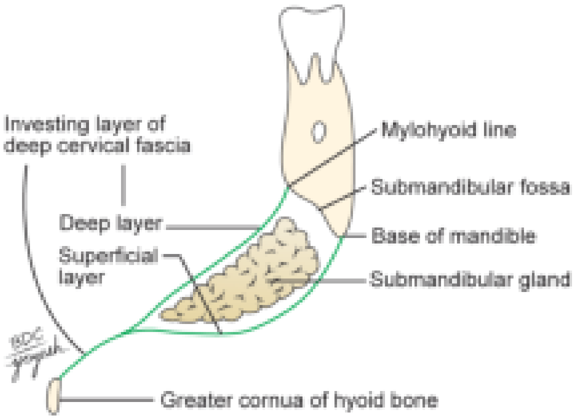

Investing layer of deep cervical fascia
Deep layer
Superficial layer
Mylohyoid line
Submandibular fossa
Base of mandible
Submandibular gland
Greater cornua of hyoid bone

Fig. 7.9: Fascial coverings of the superficial part of the submandibular salivary gland

Relations (Figs 7.10 to 7.12)

Inferior or superficial surface: It is covered by:

1. Skin
2. Platysma
3. Cervical branch of the facial nerve
4. Investing fascia
5. Facial vein
6. Submandibular lymph nodes.

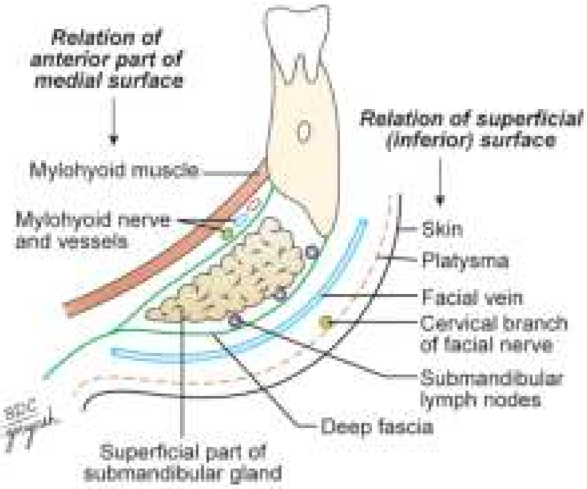

Relation of anterior part of medial surface
Mylohyoid muscle
Mylohyoid nerve and vessels
Relation of superficial (inferior) surface
Skin
Platysma
Facial vein
Cervical branch of facial nerve
Submandibular lymph nodes
Deep fascia
Superficial part of submandibular gland

Fig. 7.10: Relationship of the inferior and medial surfaces of the submandibular gland

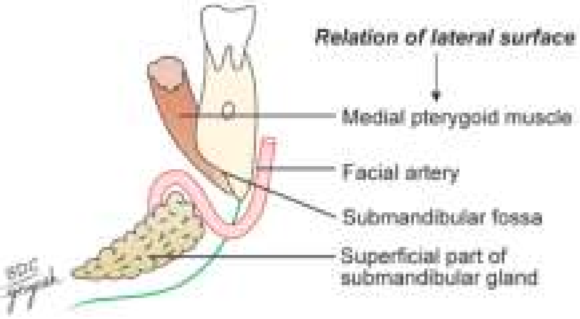

Relation of lateral surface
Medial pterygoid muscle
Facial artery
Submandibular fossa
Superficial part of submandibular gland

Fig. 7.11: Relationship of the lateral surface of the submandibular gland

Lateral surface: It is related to:

1. The submandibular fossa on the mandible
2. Insertion of the medial pterygoid
3. The facial artery.

Medial surface: It is divided into three parts which are related to:

1. *Anterior part:* Mylohyoid, submental branch of facial artery, mylohyoid nerve and vessels

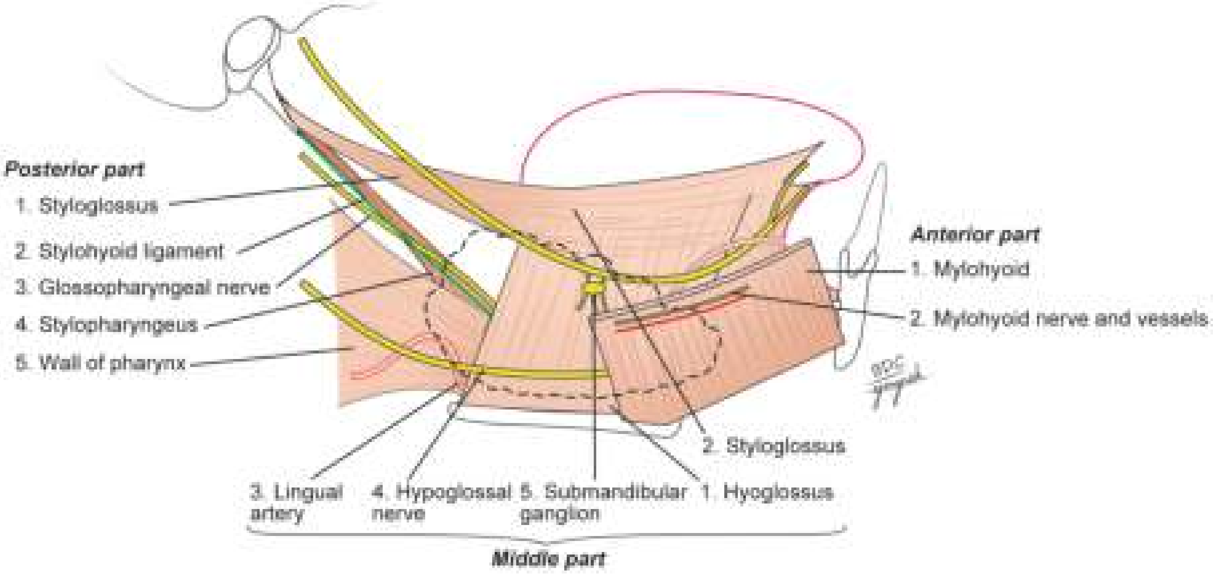

Posterior part
1. Styloglossus
2. Stylohyoid ligament
3. Glossopharyngeal nerve
4. Stylopharyngeus
5. Wall of pharynx
Anterior part
1. Mylohyoid
2. Mylohyoid nerve and vessels
2. Styloglossus
3. Lingual artery
4. Hypoglossal nerve
5. Submandibular ganglion
1. Hyoglossus
Middle part

Fig. 7.12: Relations of the medial surface of submandibular gland

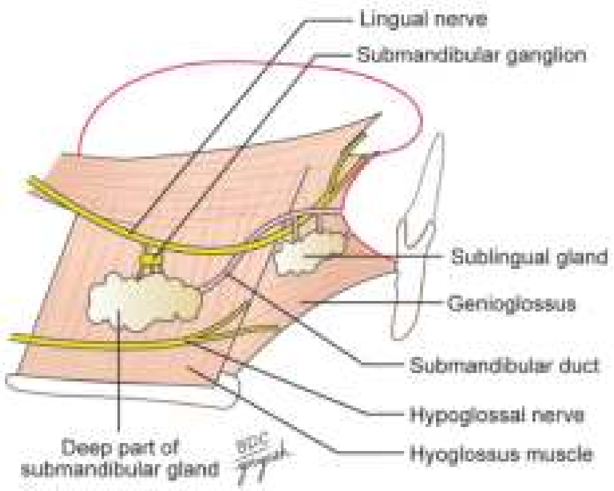

Lingual nerve
Submandibular ganglion
Sublingual gland
Genioglossus
Submandibular duct
Hypoglossal nerve
Hyoglossus muscle
Deep part of submandibular gland

Fig. 7.13: Deep part of submandibular gland and sublingual gland

2. *Middle part:* Hyoglossus, styloglossus, lingual artery, XII nerve
3. *Posterior part:* Stylohyoid, styloglossus, IX nerve.

Deep Part

This part is small in size. It lies deep to the mylohyoid and superficial to the hyoglossus and the styloglossus (Fig. 7.13). Posteriorly, it is continuous with the superficial part around the posterior border of the mylohyoid. Anteriorly, it extends up to the posterior end of the sublingual gland.

Relations

Present in between mylohyoid and hyoglossus.

Laterally: Mylohyoid (removed)

Medially: Hyoglossus

Above: Lingual nerve with submandibular ganglion

Below: Hypoglossal nerve.

Blood Supply and Lymphatic Drainage

The submandibular gland is supplied by the facial artery.

The veins drain into the common facial or lingual vein.

Lymph passes to submandibular lymph nodes.

Nerve Supply (Fig. 7.14)

It is supplied by branches from the submandibular ganglion. These branches convey:

1. Secretomotor fibres
2. Sensory fibres from the lingual nerve
3. Vasomotor sympathetic fibres from the plexus on the facial artery.

The secretomotor pathway is shown in Flowchart 7.2.

SUBMANDIBULAR DUCT/WHARTON'S DUCT

It is thin walled, and is about 5 cm long [Thomas Wharton, English anatomist, 1614–73. He also discovered Wharton's jelly of the umbilical cord].

It emerges at the anterior end of the deep part of the gland and runs upwards and forwards on the hyoglossus, between the lingual and hypoglossal nerves. At the anterior border of the hyoglossus, the duct is crossed by the lingual nerve (Fig. 7.2). It opens on the floor of the mouth, on the summit of the sublingual papilla, at the side of the frenulum of the tongue.

SUBLINGUAL SALIVARY GLAND

This is the smallest of the three salivary glands. It is almond-shaped and weighs about 3 to 4 g. It lies above the mylohyoid, below the mucosa of the floor of the mouth, medial to the sublingual fossa of the mandible and lateral to the genioglossus (Fig. 7.13).

Ducts: About 15 ducts emerge from the gland. Most of them open directly into the floor of the mouth on the summit of the sublingual fold. A few of them join the submandibular duct (*see* Fig. 17.2).

The gland receives its blood supply from the lingual and submental arteries. The nerve supply is similar to that of the submandibular gland.

DISSECTION

Submandibular gland is seen in the digastric triangle. On pushing the superficial part of the gland posteriorly, the entire mylohyoid muscle is exposed. The deep part of the gland lies on the superior surface of the muscle. Separate the facial artery from the deep surface of gland and identify its branches in neck. The hyoglossus muscle is recognised as a quadrilateral muscle lying on deeper plane than mylohyoid muscle. Identify lingual nerve with submandibular ganglion, and hypoglossal nerve running on the hyoglossus muscle from lateral to the medial side. Deep part of gland and its duct are also visible on this surface of hyoglossus muscle (Fig. 7.4).

Carefully release the hyoglossus muscle from the hyoid bone and reflect it towards the tongue. Note the structures deep to the muscle, e.g. genioglossus muscle, lingual artery, vein and middle constrictor of the pharynx.

SUBMANDIBULAR GANGLION

The submandibular ganglion is a peripheral parasympathetic ganglion [Langley's ganglion].

Neurological relationship (Fig. 7.14, Flowchart 7.2):

- *Topographic relation*: It is connected with the lingual branch of mandibular division of trigeminal nerve.
- *Functional relation*: Functionally, it is related to the facial nerve.

Size: Size of pinhead.

Location: It is located on the outer surface of the hyoglossus muscle. It is suspended from the lingual nerve by two roots. It lies deep to mylohyoid muscle.

Relations

Superior: Lingual nerve
Inferior: Deep part of submandibular gland
Superficial: Mylohyoid muscle
Deep: Hyoglossus muscle

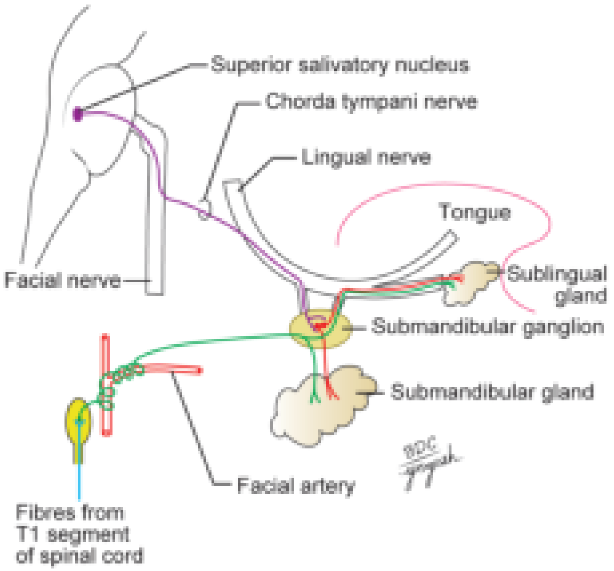

Superior salivatory nucleus
Chorda tympani nerve
Lingual nerve
Tongue
Facial nerve
Sublingual gland
Submandibular ganglion
Submandibular gland
Facial artery
Fibres from T1 segment of spinal cord

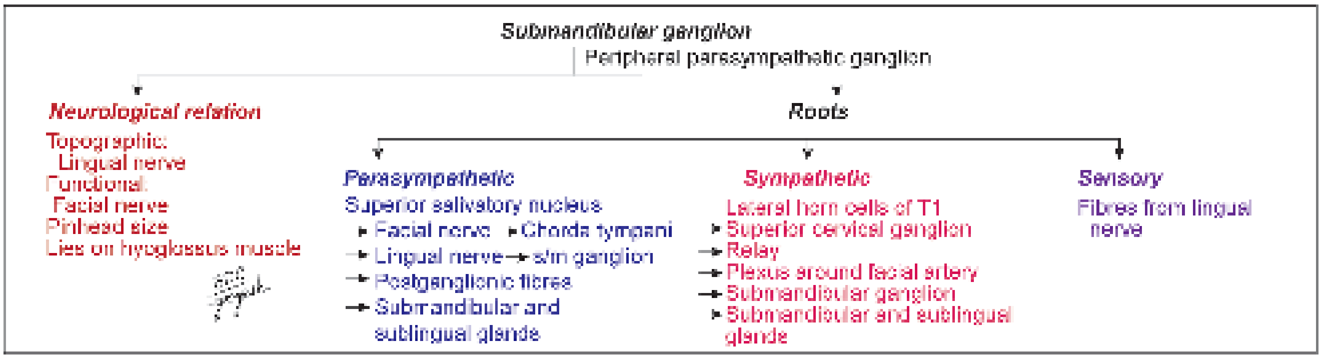
Fig. 7.14: Connection of the submandibular ganglion

Roots *(connection and distribution)*

It has three roots as follows:

1. *Parasympathetic* or *secretomotor root*: It consists of pre- and postganglionic fibres as follows:
   a. *Preganglionic fibres* begin from the *superior salivatory nucleus* in the *pons* and pass through *facial nerve*. In the facial canal, these fibres join the *chorda tympani* branch of facial nerve, which traverses through middle ear and joins the *lingual nerve* in the infratemporal fossa. Further, these fibres reach the *submandibular ganglion* through the lingual nerve, and they relay in the ganglion.
   b. *Postganglionic fibres* from the cells of submandibular ganglion join the *lingual nerve* supply sublingual gland. Few fibres from the ganglion directly supply the submandibular gland.
2. *Sympathetic root*: The lateral horn cells of *T1 segment* of spinal cord give rise to the preganglionic sympathetic fibres. They traverse through T1 nerve, sympathetic chain and relay in *superior cervical sympathetic ganglion*. Postganglionic fibres reach the submandibular ganglion through a plexus around the facial artery and pass through this ganglion without relaying. They supply submandibular and sublingual glands.

Flowchart 7.2: Submandibular ganglion


Submandibular ganglion
Peripheral parasympathetic ganglion
Neurological relation
Topographic:
Lingual nerve
Functional:
Facial nerve
Pinhead size
Lies on hyoglossus muscle
Roots
Parasympathetic
Superior salivatory nucleus
Facial nerve
Chorda tympani
Lingual nerve
s/m ganglion
Postganglionic fibres
Submandibular and sublingual glands
Sympathetic
Lateral horn cells of T1
Superior cervical ganglion
Relay
Plexus around facial artery
Submandibular ganglion
Submandibular and sublingual glands
Sensory
Fibres from lingual nerve

3. *Sensory root*: The sensory fibres from the lingual nerve pass through the submandibular ganglion without relaying.

Function

The fibres from the submandibular ganglion supply the submandibular and sublingual glands as follows:

1. Parasympathetic fibres — secretomotor
2. Sympathetic fibres — vasomotor
3. Sensory fibres — carry sensation.

HISTOLOGY

Histology of Submandibular Gland

1. Submandibular gland is mixed salivary gland. It has a well-defined capsule. Septa arising from capsule divide the gland into number of lobes and lobules (Plate 7.2).
2. *Acini*: Gland shows presence of both serous and mucous acini. Few mucous acini also show serous demilunes.
3. *Ducts*: Gland has lobar, interlobular, and intralobular (striated and intercalated) ducts. Intercalated ducts are less in number than in the parotid gland.

Histology of Sublingual Gland

1. Sublingual gland is not surrounded by well-defined capsule. Intercalated ducts are less in number than in the parotid gland (Plate 7.3).
2. *Acini*: Sublingual gland predominantly has *mucous acini*. Few serous and seromucous acini are also present. Mucous secretory units are tubular (not purely acinar).
3. *Ducts*: Sublingual gland do not have intercalated duct (rarely present), and striated ducts are also very few. Interlobular and lobar ducts are present.

Comparison of the three salivary glands is given in Table 7.3.

DEVELOPMENT

1. The submandibular and sublingual glands develop as an endodermal outgrowth from the floor of the mouth at alveolingival sulcus.
2. The submandibular gland arises as a single large bud which branches and develops to form submandibular duct and gland.
3. The sublingual gland arises as multiple small buds that form the gland with multiple ducts.

Competency:
AN34.3 Describe the basis of formation of submandibular stones.

CLINICAL ANATOMY

- ***Ranula*** is a cystic swelling in the floor of mouth due to obstruction of sublingual salivary gland. It results in mucus retention. It looks like the belly of frog (Rana hexadactyla), hence called ranula. It is a soft, bluish swelling.
- ***Injury to spine of sphenoid*** may involve both chorda tympani and auriculotemporal nerves and results into loss of secretion from all three salivary glands.
- Submandibular lymph nodes lie both within and outside the submandibular salivary gland. The gland is to be removed, if lymph nodes are affected in many diseases especially carcinoma of tongue. Cancer of the tongue or of the gland may metastasise into the mandible also.
- ***Palpation of submandibular gland***: It can be palpated bimanually by putting one finger within the mouth and one outside (Fig. 7.15).
- ***Calculi or stones in submandibular duct***: The stone is more common in the submandibular duct than the parotid duct because of:
  1. The thick secretions of submandibular gland

TABLE 7.3: Comparison of the three salivary glands

	Parotid	*Submandibular*	*Sublingual*
Location	In relation to external ear, angle of mandible, mastoid process	Lies in submandibular fossa close to angle of mandible	Lies in sublingual fossa on the base of the mandible
Size	Largest	Medium sized	Smallest
Relation to fascia	Enclosed by investing layer of cervical fascia	Enclosed by investing layer of cervical fascia	Not enclosed
Type of gland	Purely serous secreting	Mixed, both serous and mucus secreting	Purely mucus secreting
Gross features	Comprises 3 surfaces, 3 borders, apex and base, 1 artery, 1 vein, 1 nerve and lymph nodes lie within the gland	Comprises 3 surfaces, inferior, lateral and medial. 1 artery indents the posterior end of the gland. Only lymph nodes lie within it	Related closely to lingual nerve and submandibular duct
Secretomotor root	From IX cranial nerve	From VII cranial nerve	From VII cranial nerve
Sympathetic root	Plexus around middle meningeal artery	Plexus around facial artery	Same as submandibular gland
Sensory	Auriculotemporal nerve	Lingual nerve	Lingual nerve
Development	Ectoderm	Endoderm	Endoderm
Opening of the duct	Vestibule of mouth opposite 2nd upper molar tooth	Papilla on sublingual fold in the floor of the mouth	10–12 ducts open on sublingual fold in the floor of the mouth

Plate 7.2: Histology of submandibular gland

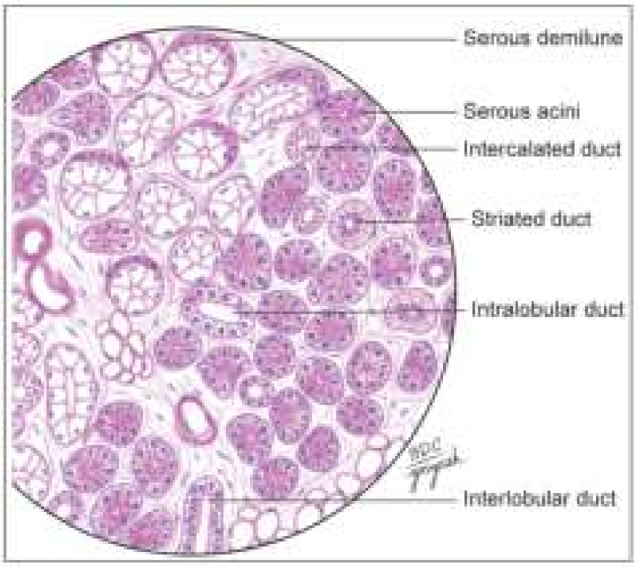
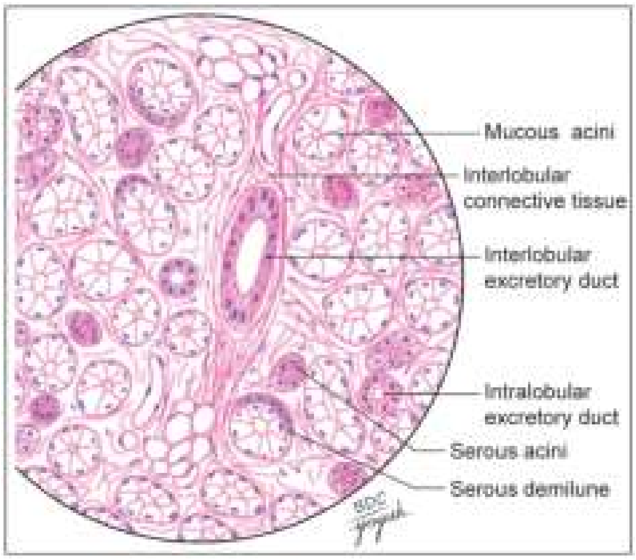

Serous demilune
Serous acini
Intercalated duct
Striated duct
Intralobular duct
Interlobular duct

Plate 7.3: Histology of sublingual gland


Mucous acini
Interlobular connective tissue
Interlobular excretory duct
Intralobular excretory duct
Serous acini
Serous demilune

2. Tortuous and antigravity (upwards) course of the submandibular duct.

- The stone of the submandibular gland can be palpated or detected radiologically. It may require surgical removal.

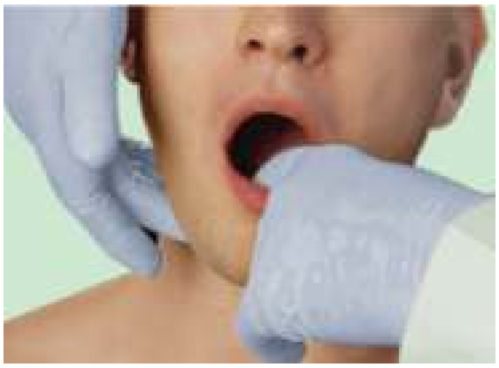


Fig. 7.15: Bimanual palpation of submandibular gland and lymph nodes

Video 3.7 **Submandibular Salivary Gland**

Facts to Remember

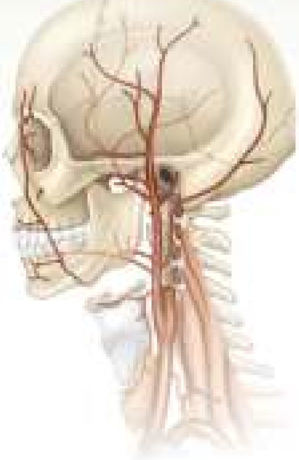
- Chorda tympani nerve carries secretomotor fibres to the submandibular ganglion. It also carries taste from most of the anterior two-thirds of the tongue.
- The submandibular lymph nodes are also present in the submandibular gland. In cancer of the tongue, this gland is also excised to get rid off the lymph nodes with secondaries from the tongue.
- Facial artery is tortuous to accommodate to the movements of pharynx. It is the chief artery of the palatine tonsil. Its course is S-shaped.
- Suprahyoid muscles are disposed in four layers:
  - 1st layer: Digastric and stylohyoid
  - 2nd layer: Mylohyoid
  - 3rd layer: Geniohyoid and hyoglossus
  - 4th layer: Genioglossus

BDC's Anatomy *e*-book

1. Relation of marginal mandibular branch of facial nerve
2. Relations of sublingual gland
3. Further reading
4. Viva voce questions

Chapter

8



Structures in the Neck

There are numerous structures in the neck. For convenience, they may be grouped as follows:

1. *Glands:* Thyroid and parathyroid
2. *Thymus:* Involutes at puberty
3. *Arteries:* Subclavian and carotid
4. *Veins:* Subclavian, internal jugular and brachiocephalic
5. *Nerves:* Glossopharyngeal, vagus, accessory and hypoglossal
6. *Sympathetic trunk:* It has three cervical ganglia
7. Lymph nodes and thoracic duct
8. Styloid apparatus.

Competency:
AN35.2 Describe and demonstrate location, parts, borders, surfaces, relations and blood supply and applied anatomy of thyroid gland. Also describe the parathyroid glands in brief.

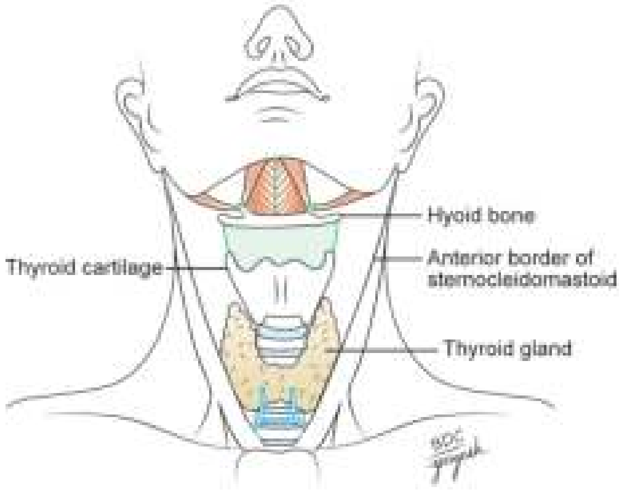

Hyoid bone
Thyroid cartilage
Anterior border of sternocleidomastoid
Thyroid gland

Fig. 8.1: Position of thyroid gland

THYROID GLAND

The thyroid (shield-like, Greek) is an endocrine gland with a rich blood supply situated in the lower part of the front and sides of the neck. Since, it is placed superficially, it can easily be examined (Figs 8.1 and 8.2, Flowchart 8.1).

Functions

1. It secretes tri-iodothyronine (T3), tetra-iodothyronine (T4), or thyroxine and calcitonin.
2. It regulates the basal metabolic rate.
3. It promotes the psychosomatic growth of the body.
4. It modulates the calcium metabolism.

Parts of Thyroid Gland (Fig. 8.2)

The gland is H-shaped and consists of the following parts:

1. Two lobes — right and left
2. *Isthmus* — connects both lobes
3. Pyramidal lobe — may project upwards from the isthmus (or from one of the lobes).

Note: ***Levator glandulae thyroideae*** is a fibrous or fibromuscular band that is sometimes present and connects the pyramidal lobe to the body of the hyoid bone.

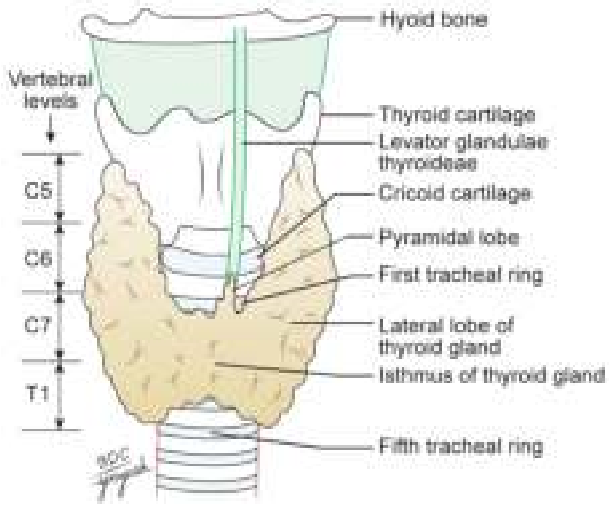
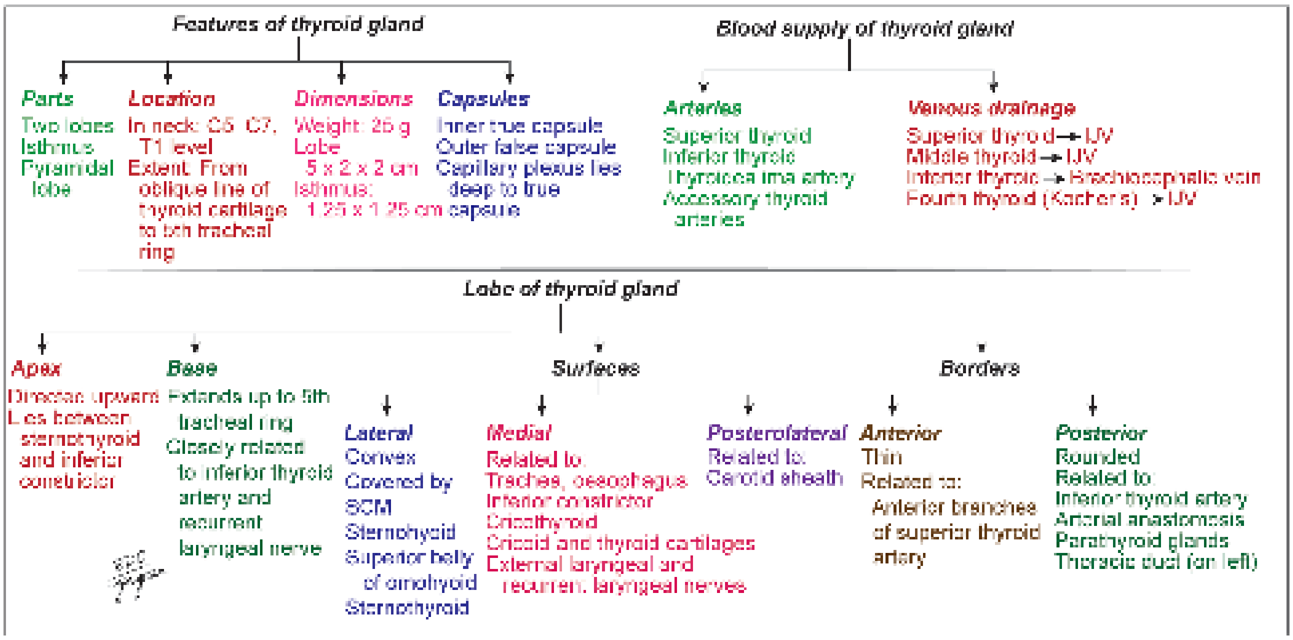

Vertebral levels
C5
C6
C7
T1
Hyoid bone
Thyroid cartilage
Levator glandulae thyroideae
Cricoid cartilage
Pyramidal lobe
First tracheal ring
Lateral lobe of thyroid gland
Isthmus of thyroid gland
Fifth tracheal ring

Fig. 8.2: Parts and extent of the thyroid gland

Location and Extent (Fig. 8.1)

1. The gland lies against vertebrae C5–C7 and T1, embracing the upper part of the trachea (Fig. 8.1).
2. Each *lobe* extends from the middle of thyroid cartilage to the 4th or 5th tracheal rings. The lobe is prevented

Flowchart 8.1: Thyroid gland


Features of thyroid gland
Parts
Two lobes
Isthmus
Pyramidal lobe
Location
In neck: C5, C7, T1 level
Extent: From oblique line of thyroid cartilage to 5th tracheal ring
Dimensions
Weight: 25 g
Lobe 5 x 2 x 2 cm
Isthmus: 1.25 x 1.25 cm
Capsules
Inner true capsule
Outer false capsule
Capillary plexus lies deep to true capsule
Blood supply of thyroid gland
Arteries
Superior thyroid
Inferior thyroid
Thyroidea ima artery
Accessory thyroid arteries
Venous drainage
Superior thyroid → IJV
Middle thyroid → IJV
Inferior thyroid → Brachiocephalic vein
Fourth thyroid (Kocher's) → IJV
Lobe of thyroid gland
Apex
Directed upward
Lies between sternothyroid and inferior constrictor
Base
Extends up to 5th tracheal ring
Closely related to inferior thyroid artery and recurrent laryngeal nerve
Surfaces
Lateral
Convex
Covered by
SCM
Sternohyoid
Superior belly of omohyoid
Sternothyroid
Medial
Related to:
Trachea, oesophagus
Inferior constrictor
Cricothyroid
Cricoid and thyroid cartilages
External laryngeal and recurrent laryngeal nerves
Posterolateral
Related to:
Carotid sheath
Borders
Anterior
Thin
Related to:
Anterior branches of superior thyroid artery
Posterior
Rounded
Related to:
Inferior thyroid artery
Arterial anastomosis
Parathyroid glands
Thoracic duct (on left)

(IJV: Internal jugular vein, SCM: Sternocleidomastoid)

from ascending by thyrohyoid muscle. It is prevented from descending down by *ligament of Berry*.

3. The *isthmus* extends from the 2nd to the 4th tracheal ring.

Dimensions and Weight

Each lobe measures about 5 × 2.5 × 2.5 cm and the isthmus 1.2 × 1.2 cm. On average, the gland weighs about 25 g.

Note: The thyroid gland is larger in females than in males, and further increases in size during menstruation and pregnancy.

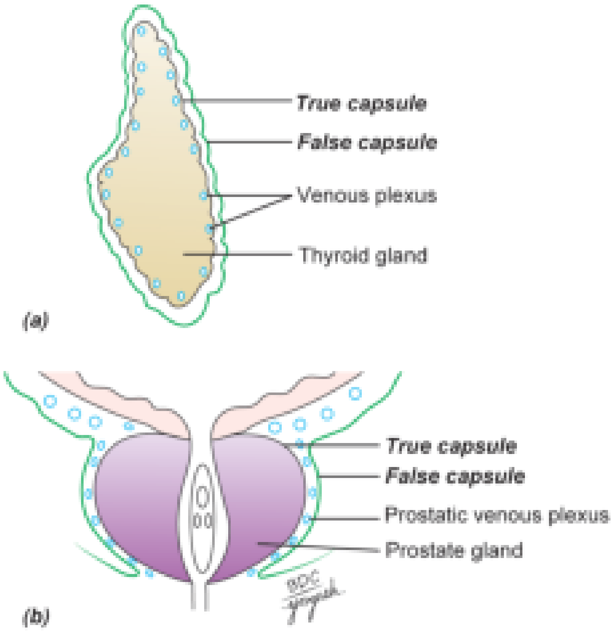
Capsules of Thyroid (Figs 8.3a and b)

The thyroid gland has two capsules: Inner true capsule and outer false capsule:

1. ***True capsule:*** It is the peripheral condensation of the connective tissue of the gland.
2. ***False capsule:*** It is derived from the pretracheal layer of the deep cervical fascia.

   Features of false capsule

   a. It is thin along the posterior border of the lateral lobe.
   b. It is thicker on the medial surface of the lateral lobe.
   c. *Suspensory ligament of Berry*: It is a thickened part of pretracheal fascia (false capsule) that connects the lobes of thyroid gland with the cricoid cartilage.


True capsule
False capsule
Venous plexus
Thyroid gland
(a)
True capsule
False capsule
Prostatic venous plexus
Prostate gland
(b)

Figs 8.3a and b: Schemes of comparing the relationship of the venous plexuses related to (a) The thyroid gland and (b) the prostate, with the true and false capsules around these organs. Note the plane of cleavage along which the organ is separated from neighbouring structures during surgical removal

CLINICAL ANATOMY

- A dense capillary plexus is present deep to the true capsule. To avoid haemorrhage during operations, the thyroid is removed along with the true capsule. It can be compared with the prostate in which the venous plexus lies between the two capsules of the gland, and therefore, during prostatectomy, both capsules are left behind (Figs 8.3a and b).
- In prostatic surgeries, the venous plexus lies between two capsules. Hence, the prostate should be removed, leaving behind both capsules.
- As the capsule of the thyroid gland is thin along the posterior border, its swelling more commonly extends backward rather than forming a visible swelling in the neck.
- ***Swallowing and thyroid movements***: The thyroid moves up and down during swallowing as it is attached to the cricoid cartilage by the ligament of Berry.

Parts and Relations of Lobes

The lobes are conical in shape having (Figs 8.4 and 8.5):

a. Apex
b. Base
c. Three surfaces: Lateral, medial and posterolateral
d. Two borders: Anterior and posterior.

Apex

It is directed upwards and slightly laterally.

It is limited superiorly by the attachment of the sternothyroid muscle to the oblique line of thyroid cartilage which is medial to the apex. Thus it lies between inferior constrictor and sternothyroid muscles. The apex is related to superior thyroid artery and the external laryngeal nerve.

Base

It is at level with the 4th or 5th tracheal ring.

It is related to inferior thyroid artery and recurrent laryngeal nerve.

Lateral or superficial surface is convex, and is covered by:

a. Sternohyoid
b. Superior belly of omohyoid
c. Sternothyroid
d. Anterior border of the sternocleidomastoid.

Medial surface is related to:

a. Two tubes—trachea and oesophagus
b. Two muscles—inferior constrictor and cricothyroid
c. Two nerves—external laryngeal and recurrent laryngeal
d. Two cartilages—thyroid and cricoid.

Posterolateral surface is related to the carotid sheath and overlaps the common carotid artery.

Anterior border is thin and is related to the anterior branch of superior thyroid artery

Posterior border is thick and rounded and separates the medial and posterior surfaces. It is related to:

a. Inferior thyroid artery
b. Anastomosis between the posterior branch of superior and ascending branch of inferior thyroid arteries
c. Parathyroid glands
d. Thoracic duct only on the left side.

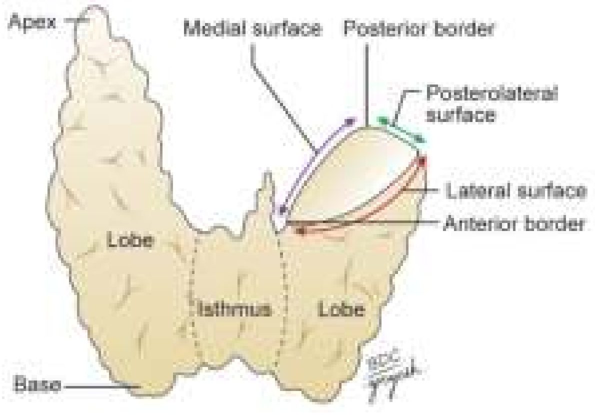

Apex
Medial surface
Posterior border
Posterolateral surface
Lateral surface
Anterior border
Lobe
Isthmus
Lobe
Base
BDC

Fig. 8.4: Parts of lobes of the thyroid gland

Parts and Relations of Isthmus

Isthmus connects the lower parts of the two lobes (Figs 8.5 and 8.6).

It has:

Two surfaces: Anterior and posterior

Two borders: Superior and inferior.

- *Anterior surface* is covered by:
  a. Right and left sternothyroid and sternohyoid muscles
  b. Anterior jugular veins
  c. Fascia and skin.
- *Posterior surface* is related to the 2nd to 4th tracheal rings.
- *Upper border* is related to anterior branches of the right and left superior thyroid arteries which anastomose here.
- *Lower border:* Inferior thyroid veins leave the gland at this border.

Arterial Supply

The thyroid gland is supplied by the superior and inferior thyroid arteries (Figs 8.6 to 8.8).

1. ***Superior thyroid artery*** is the 1st anterior branch of the external carotid artery. It runs downwards and forwards in intimate relation to the external laryngeal nerve. After giving branches to adjacent structures, the artery pierces the pretracheal fascia to reach the apex of the lobe where the nerve deviates medially.

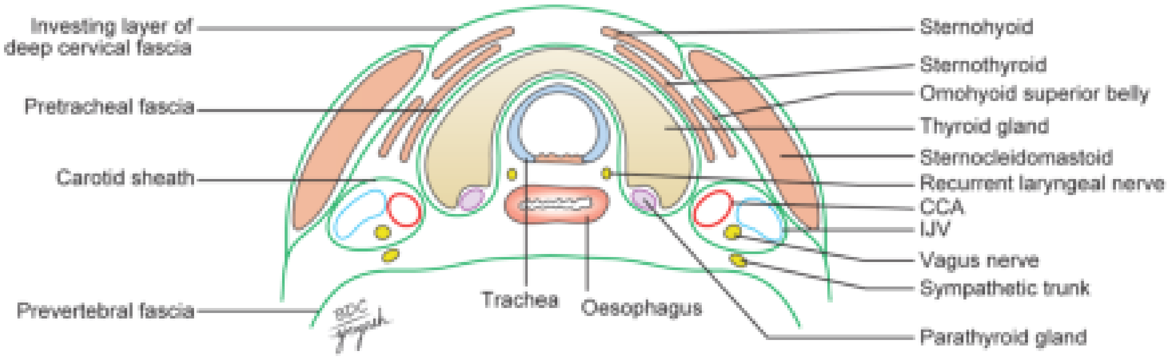

Investing layer of deep cervical fascia
Pretracheal fascia
Carotid sheath
Prevertebral fascia
Trachea
Oesophagus
Sternohyoid
Sternothyroid
Omohyoid superior belly
Thyroid gland
Sternocleidomastoid
Recurrent laryngeal nerve
CCA
IJV
Vagus nerve
Sympathetic trunk
Parathyroid gland
BDC

Fig. 8.5: Relations of thyroid gland (transverse section of the anterior part of the neck at the level of thyroid isthmus, inferior view. CCA: Common carotid artery, IJV: Internal jugular vein)

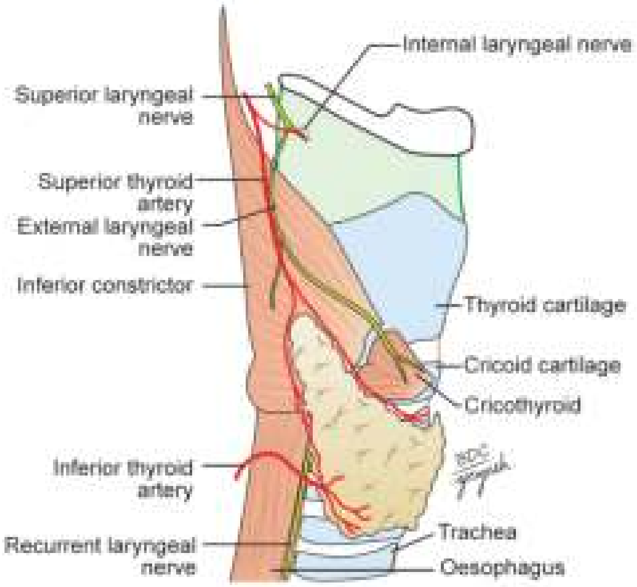

Internal laryngeal nerve
Superior laryngeal nerve
Superior thyroid artery
External laryngeal nerve
Inferior constrictor
Thyroid cartilage
Cricoid cartilage
Cricothyroid
Inferior thyroid artery
Recurrent laryngeal nerve
Trachea
Oesophagus
BDC

Fig. 8.6: Deep relations of the thyroid gland

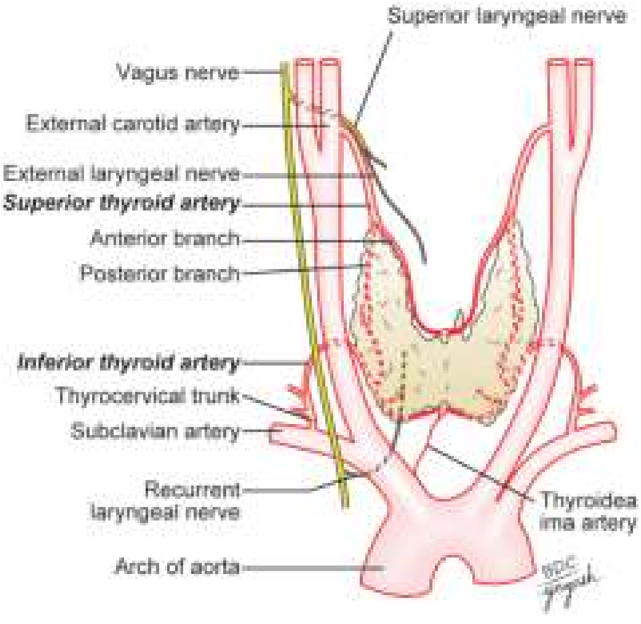

Superior laryngeal nerve
Vagus nerve
External carotid artery
External laryngeal nerve
Superior thyroid artery
Anterior branch
Posterior branch
Inferior thyroid artery
Thyrocervical trunk
Subclavian artery
Recurrent laryngeal nerve
Thyroidea ima artery
Arch of aorta
BDC

Fig. 8.7: Arterial supply of anterior aspect of thyroid gland

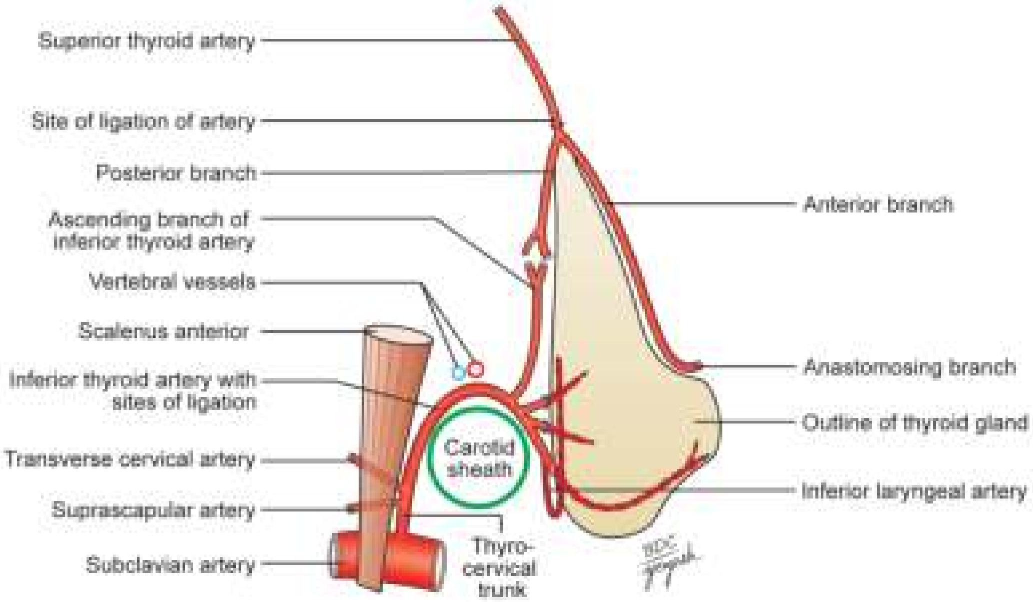

Superior thyroid artery
Site of ligation of artery
Posterior branch
Ascending branch of inferior thyroid artery
Vertebral vessels
Scalenus anterior
Inferior thyroid artery with sites of ligation
Transverse cervical artery
Suprascapular artery
Subclavian artery
Carotid sheath
Thyro-cervical trunk
Anterior branch
Anastomosing branch
Outline of thyroid gland
Inferior laryngeal artery
BDC

Fig. 8.8: Arterial supply of the surfaces of thyroid gland. Sites of ligatures of the superior and inferior thyroid arteries are shown

At the upper pole, the artery divides into anterior and posterior branches.

  a. The ***anterior branch*** descends on the anterior border of the lobe and continues along the upper border of the isthmus to anastomose with its counterpart on the opposite side.
  b. The ***posterior branch*** descends on the posterior border of the lobe and anastomoses with the ascending branch of inferior thyroid artery.

2. ***Inferior thyroid artery*** is a branch of thyrocervical trunk (which arises from the subclavian artery). It runs first upwards, then medially, and finally downwards to reach the base of the gland. It gives off branches to adjacent structures. Its terminal part is intimately related to the recurrent laryngeal nerve, while proximal part is away from the nerve.

   The artery divides into ***4 to 5 glandular branches*** which pierce the fascia separately to reach the lower part of the gland. One ***ascending branch*** anastomoses with the posterior branch of the superior thyroid artery and supplies the parathyroid glands.
3. Sometimes (in 3% of individuals), the thyroid is also supplied by the ***lowest thyroid artery (thyroidea ima artery)*** which arises from the brachiocephalic trunk or directly from the arch of the aorta. It enters the lower part of the isthmus.
4. ***Accessory thyroid arteries*** arising from tracheal and oesophageal arteries also supply the thyroid.

Venous Drainage

The thyroid is drained by the superior, middle and inferior thyroid veins (Fig. 8.9).

1. ***Superior thyroid vein*** emerges at the upper pole and accompanies the superior thyroid artery. It ends in the internal jugular vein.
2. ***Middle thyroid vein*** is a short, wide channel that emerges at the middle of the lobe and soon enters the internal jugular vein.
3. ***Inferior thyroid veins*** emerge at the lower border of isthmus. They form a plexus in front of the trachea and drain into the left brachiocephalic vein.
4. ***Fourth thyroid vein*** **(Kocher)** may emerge between the middle and inferior veins, and drain into the internal jugular vein.

Lymphatic Drainage

Lymph from the upper part of the gland reaches the upper deep cervical lymph nodes either directly or through the prelaryngeal nodes. Lymph from the lower part of the gland drains to the lower deep cervical nodes directly, and also through the pretracheal and paratracheal nodes (Fig. 8.10).

Nerve Supply

Nerves are derived mainly from the middle cervical ganglion and partly from the superior and inferior cervical ganglia. These are vasoconstrictor.

DISSECTION

Sternocleidomastoid muscle has already been reflected laterally from its origin. Cut the sternothyroid muscle near its origin and reflect it upwards. Clean the surface of trachea and identify inferior thyroid vein and remains of the thymus gland (darker in colour than fat).

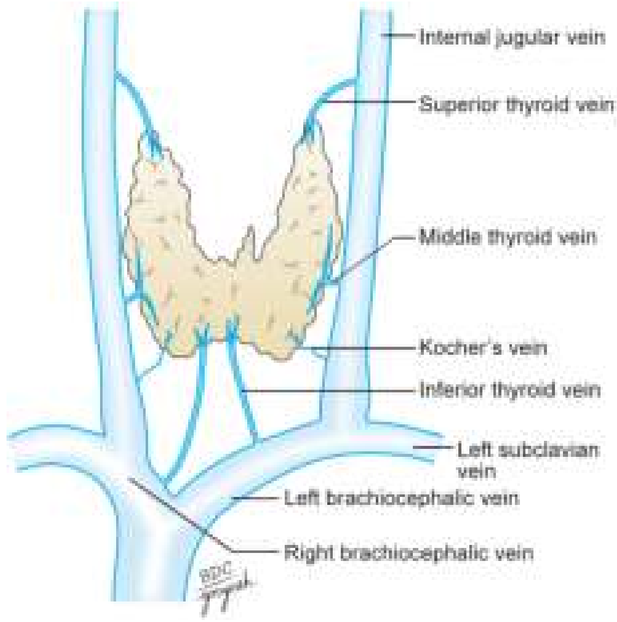


Fig. 8.9: Venous drainage and lymphatic drainage of the thyroid gland. Deep cervical lymph nodes are also shown

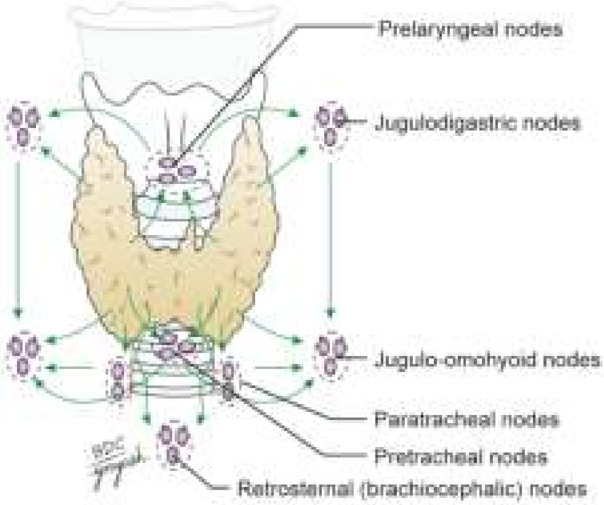


Fig. 8.10: Lymphatic drainage of the thyroid gland

Isthmus of the thyroid gland lies on the 2nd–4th tracheal rings. Pyramidal lobe, if present, projects from the upper border of the isthmus. On each side of isthmus is the lateral lobe of the gland. Clean the lobes and identify the vessels of thyroid gland. Identify the recurrent laryngeal nerves tucked between the lateral surfaces of trachea and oesophagus. Look for beaded thoracic duct present on the left of oesophagus. Trace the superior and inferior thyroid arteries. Identify cricothyroid and inferior constrictor muscles lying medial to the lobes of thyroid gland (Figs 8.1 to 8.6).

Thyroid gland (butterfly shaped)

Cut the isthmus of the thyroid gland and turn one of the lobes laterally. Locate an anastomosis between the posterior branch of superior thyroid and ascending branch of inferior thyroid arteries supplying the gland. Identify the two parathyroid glands on the sides of this anastomotic vessel (Figs 8.7 and 8.12).

Competency:

AN35.8 Describe the anatomically relevant clinical features of thyroid swellings.

CLINICAL ANATOMY

- Any swelling of the thyroid gland (***goitre)*** should be palpated from behind (Figs 8.11 and 8.12).
- Removal of the thyroid (***thyroidectomy***) with true capsule may be necessary in hyperthyroidism.
- In subtotal thyroidectomy, the posterior parts of both lobes are left behind. This avoids the risk of simultaneous removal of the parathyroids and also of postoperative myxoedema (caused by deficiency of thyroid hormones).
- During thyroidectomy, the superior thyroid artery is ligated near the gland to save the external laryngeal nerve. The stem of inferior thyroid artery is not ligated (Fig. 8.7). Its glandular branches are ligated

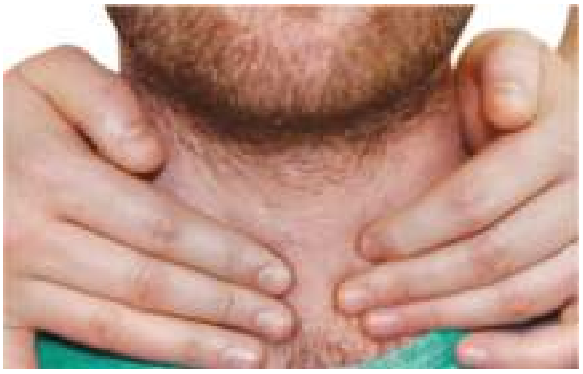


Fig. 8.11: Palpation of thyroid gland from behind

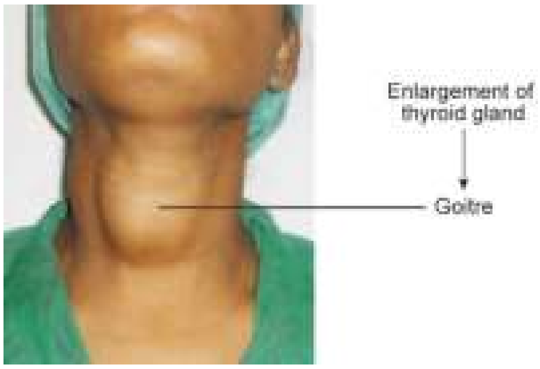


Fig. 8.12: Goitre (*Image Courtesy*: Dr Uday Kumbhar)

separately. In this way, blood supply to parathyroid glands is maintained.

- ***Hypothyroidism*** causes cretinism in infants and myxoedema in adults.
- Benign ***tumours*** of the gland may displace and even compress neighbouring structures such as:
  - a. Trachea — causing dyspnoea (difficulty in breathing)
  - b. Oesophagus — causing dysphagia (difficulty in swallowing)
  - c. Recurrent laryngeal nerve — dysphonia (hoarseness of voice).

Competency:

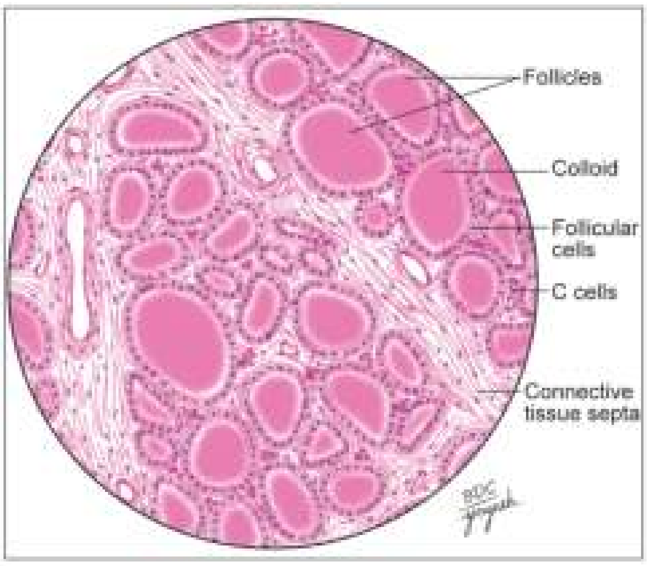
AN43.2 Identify, describe and draw the microanatomy of pituitary gland, thyroid, parathyroid gland, tongue, salivary glands, tonsil, cornea, retina.

Microanatomy of thyroid and parathyroid glands is described in this chapter. Rest of the tissues/glands are described in appropriate chapters.

Histology of Thyroid Gland (Plate 8.1)

- Thyroid gland is covered by thin connective tissue capsule. Septa arising from capsule divide the gland into number of lobules.
- Thyroid gland is made up of ***follicles*** lined by simple cuboidal epithelium (ranges from squamous to low columnar) with rounded nuclei.
- Lumen of follicle contains pink homogeneous ***colloid*** material that consists of thyroglobulin.

Plate 8.1: Histology of thyroid gland



- Few ***parafollicular/C-cells*** are present in relation to follicles. C-cells secrete calcitonin that reduces blood calcium levels.
- In between follicles, rich vascular connective tissue is present.

Competency:

AN43.4 Describe the development and developmental basis of congenital anomalies of face, palate, tongue, branchial apparatus, pituitary gland, thyroid gland and eye.

Development of thyroid gland is described in this chapter. For development of rest of the organs, please refer to appropriate chapters.

Development of Thyroid Gland

Thyroid gland develops from the following two sources (Fig 8.13):

A. Follicles from thyroglossal duct.
B. Parafollicular cells from ultimobranchial body (a part of caudal pharyngeal complex).

On the floor of the primitive pharynx, over the first arch in the midline, there is a swelling called *tuberculum impar*. By the 24th day, just behind tuberculum impar, pharyngeal epithelium forms a depression (endodermal diverticulum) called *thyroglossal duct*. The opening of thyroglossal duct in the pharynx is represented by the *foramen caecum*.

By the end of the third month (12th week), follicular cells start producing thyroid hormones. The thyroid gland is the first gland that develops after fertilisation.

Anomalies of Thyroid Gland

1. Sometimes, isthmus or one lobe of the thyroid gland may be absent or small.
2. *Anomalies of location*: The thyroid gland may lie at any position at the passage of thyroglossal duct. It may be lingual, intralingual, suprahyoid, or infrahyoid thyroid gland (Fig. 8.14).

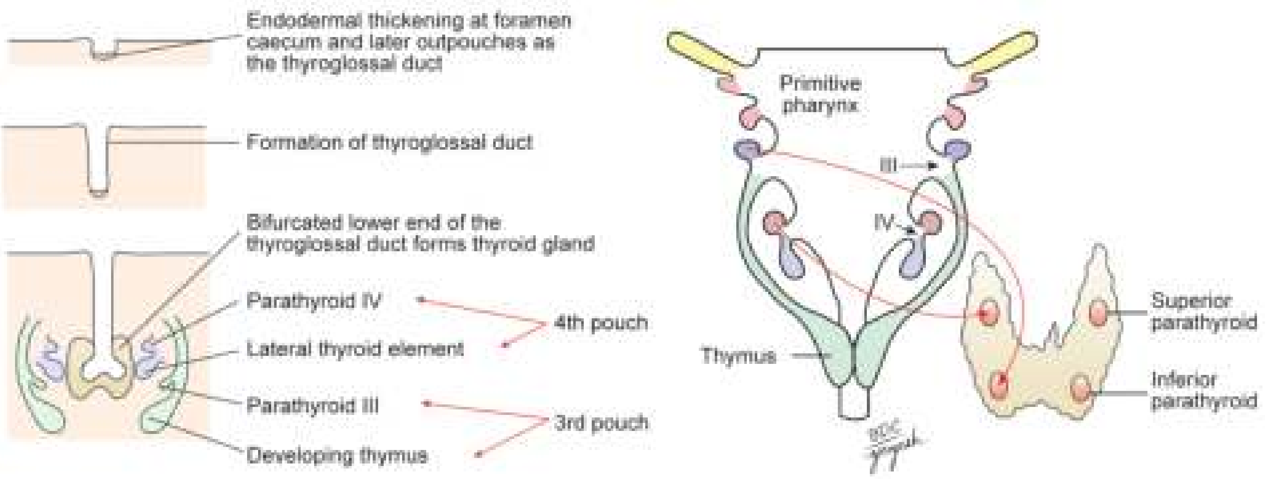

Endodermal thickening at foramen caecum and later outpouches as the thyroglossal duct
Formation of thyroglossal duct
Bifurcated lower end of the thyroglossal duct forms thyroid gland
Parathyroid IV
Lateral thyroid element
4th pouch
Parathyroid III
3rd pouch
Developing thymus
Primitive pharynx
III
IV
Thymus
Superior parathyroid
Inferior parathyroid

Fig. 8.13: Development of thyroid, parathyroid and thymus glands. Parathyroids are placed posteriorly

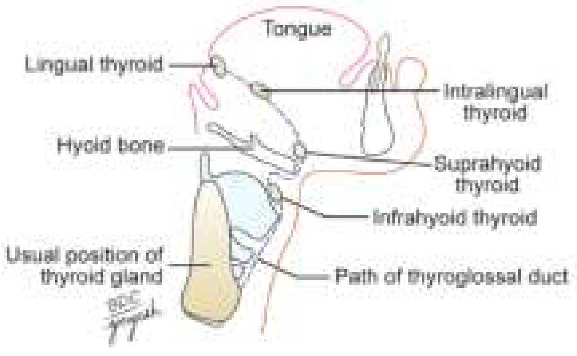
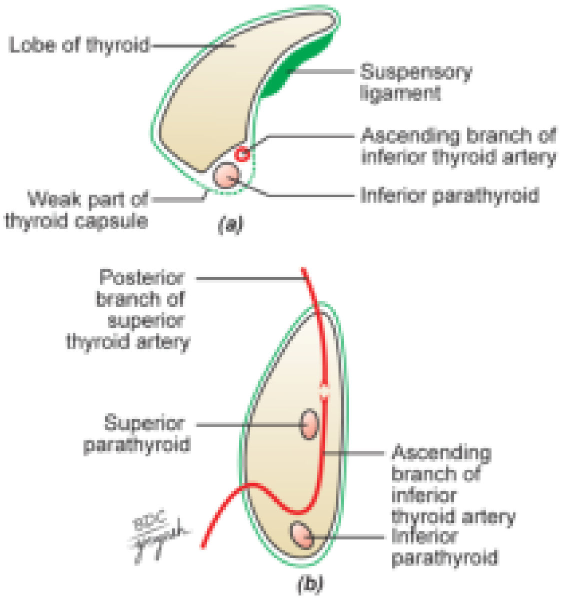

Tongue
Lingual thyroid
Intralingual thyroid
Hyoid bone
Suprahyoid thyroid
Infrahyoid thyroid
Usual position of thyroid gland
Path of thyroglossal duct

Fig. 8.14: Anomalies of the position of the thyroid gland and locations of the thyroglossal cyst

3. *Ectopic thyroid tissue*: Ectopic thyroid is the presence of thyroid tissue in locations other than usual (normal) thyroid gland locations. It is mostly found in larynx, trachea, oesophagus, pericardium and ovaries.


Lobe of thyroid
Suspensory ligament
Ascending branch of inferior thyroid artery
Inferior parathyroid
Weak part of thyroid capsule
(a)
Posterior branch of superior thyroid artery
Superior parathyroid
Ascending branch of inferior thyroid artery
Inferior parathyroid
(b)

Figs 8.15a and b: Schemes to show the location of the parathyroid glands: (a) The left lobe of the thyroid gland and (b) posterior view of the left lobe of the thyroid gland

PARATHYROID GLANDS

Parathyroid glands are two pairs (superior and inferior) of small endocrine glands, that usually lie on the posterior border of the thyroid gland, within the false capsule (Figs 8.15a and b).

1. The *superior parathyroids* are also referred to as *parathyroid IV* because they develop from the endoderm of the *4th pharyngeal pouch*.
2. The *inferior parathyroids*, similarly, are also called *parathyroid III* because they develop from the *3rd pouch*.

The parathyroids secrete the hormone *parathormone* which controls the metabolism of calcium and phosphorus along with thyrocalcitonin.

Each parathyroid gland is oval or lentiform in shape, measuring 6 × 4 × 2 mm (the size of a split pea). Each gland weighs about 50 mg.

Position

The *superior parathyroid* is more constant in position and usually lies in the middle of the posterior border of the lobe of the thyroid gland. It is usually dorsal to the recurrent laryngeal nerve.

The *inferior parathyroid* is more variable in position. It may lie:

1. Within the thyroid capsule, below the inferior thyroid artery and near the lower pole of the thyroid lobe.
2. Behind and outside the thyroid capsule, immediately below the inferior thyroid artery.
3. Within the substance of the lobe near its posterior border. It is usually ventral to the recurrent laryngeal nerve.

Note: The anastomosis between the branches of superior and inferior thyroid arteries is usually a good guide to the glands because they usually lie close to it.

Vascular Supply

The parathyroid glands receive a rich blood supply from the inferior thyroid artery and from the anastomosis between the branches of superior and inferior thyroid arteries. The veins and lymphatics of the gland are associated with those of the thyroid and the thymus.

Nerve Supply

Vasomotor nerves are derived from the middle and superior cervical ganglia. Parathyroid activity is controlled by blood calcium levels; low levels stimulate and high levels inhibit the activity of the glands.

CLINICAL ANATOMY

- ***Tumours*** of the parathyroid glands lead to excessive secretion of parathormone (hyperparathyroidism). This leads to increased removal of calcium from bone, making them weak and liable to fracture. Calcium levels in blood increase (hypercalcaemia) and increased urinary excretion of calcium can lead to the formation of stones in the urinary tract.
- ***Hypoparathyroidism*** may occur spontaneously or from accidental removal of the glands during thyroidectomy. This results in hypocalcaemia leading to increased neuromuscular irritability causing muscular spasm and convulsions (tetany) (Fig. 8.16).
- Parathyroid glands are tough glands and will continue to function, if these are transplanted from an excised thyroid gland into the sternocleidomastoid muscle.

Histology of Parathyroid Gland (Plate 8.2)

Parathyroid gland shows cords or sheets of cells separated by numerous capillaries.

- It shows two types of cells: (1) chief, and (2) oxyphil cells.
- *Chief cells* are more in number, small in size, and consist of a spherical nucleus with small amount of cytoplasm. They secrete PTH hormone.

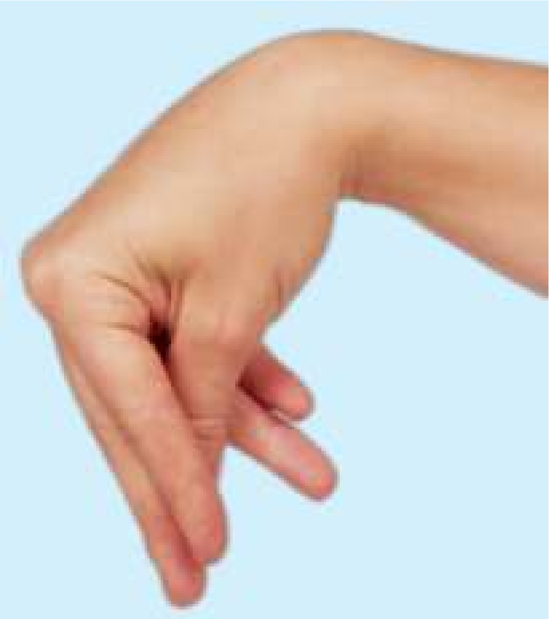
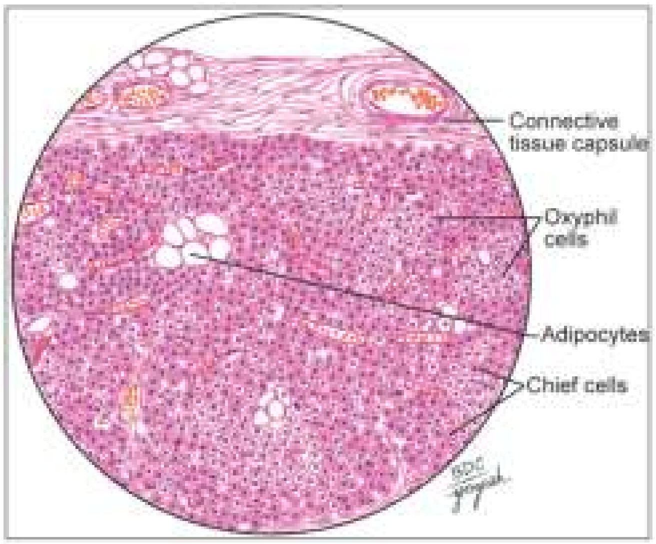


Fig. 8.16: Spasm in the hand due to tetany

Plate 8.2: Histology of the parathyroid gland



- *Oxyphil (eosinophilic) cells* are less in number, larger in size, and small intense-staining nucleus with eosinophilic cytoplasm. They do not secrete any hormones. Oxyphilic cells appear just before puberty.

Development of Parathyroid Glands

Inferior parathyroid glands: They are derived from the dorsal wing of the 3rd pharyngeal pouch.

- Primordia of the inferior parathyroids along with primordia of thymus lose their connection with the pharyngeal wall.
- The downward migrating thymus also pulls the inferior parathyroids with it, which finally come to rest on the inferior part of dorsal surface of the thyroid gland.

Superior parathyroid glands: They are derived from the endoderm of 4th pharyngeal pouch.

- The primordia of superior parathyroid glands, after losing connection with the pharyngeal wall, come to rest on the superior part of dorsal surface of the thyroid gland.
- As mentioned above, because of downwards migration with the thymus, the parathyroid glands derived from 3rd pouch become inferiorly located as compared to those derived from the 4th pouch.

THYMUS

The thymus (Greek *thyme leaf*) is an important lymphoid organ, situated in the anterior and superior mediastina of the thorax, extending above into the lower part of the neck. It is well developed at birth, continues to grow up to puberty, and thereafter, undergoes gradual atrophy and replacement by fat.

The thymus is a bilobed structure, made up of two pyramidal lobes of unequal size which are connected together by areolar tissue.

Each lobe develops from the endoderm of the 3rd pharyngeal pouch. It lies on the pericardium, the great vessels of the superior mediastinum, and the trachea.

The thymus weighs 10–15 g at birth, 30–40 g at puberty, and only 10 g after mid-adult life. Thus, after puberty, it becomes inconspicuous due to replacement by fat.

Blood Supply

The thymus is supplied by branches from the internal thoracic and inferior thyroid arteries. Its veins drain into the left brachiocephalic, internal thoracic and inferior thyroid veins.

Nerve Supply

Vasomotor nerves are derived from the stellate ganglion. The capsule is supplied by the phrenic nerve and by the descendens cervicalis.

Functions

1. The thymus controls lymphopoiesis and maintains an effective pool of circulating lymphocytes, competent to react to innumerable antigenic stimuli.
2. It controls development of the peripheral lymphoid tissues of the body during the neonatal period. By puberty, the main lymphoid tissues are fully developed.
3. The cortical lymphocytes of the thymus arise from stem cells of bone marrow origin. Most (95%) of the lymphocytes (T lymphocytes) produced are autoallergic (act against the host or 'self' antigens), short-lived (3–5 days) and never move out of the organ. They are destroyed within the thymus by phagocytes. Their remnants are seen as Hassall's corpuscles.
4. The remaining 5% of the T lymphocytes are longlived (3 months or more), and move out of the thymus to join the circulating pool of lymphocytes where they act as immunologically competent but uncommitted cells, i.e. they can react to any unfamiliar, new antigen. On the other hand, the other circulating lymphocytes (from lymph nodes, spleen, etc.) are committed cells, i.e. they can mount an immune response only when exposed to a particular antigen. Thymic lymphopoiesis, lympholysis and involution are all intrinsically controlled.
5. The medullary epithelial cells of the thymus are thought to secrete:
   a. *Lymphopoietin*, which stimulates lymphocyte production both in the cortex of the thymus and in peripheral lymphoid organs.
   b. The *competence-inducing factor*, which may be responsible for making new lymphocytes competent to react to antigenic stimuli.
6. Normally, there are no germinal centres in the thymic cortex. Such centres appear in autoimmune diseases. This may indicate a defect in the normal function of the thymus.

CLINICAL ANATOMY

- ***Involution*** of the thymus is enhanced by hypertrophy of the adrenal cortex, injection of cortisone or of androgenic hormone. The involution is delayed by castration and adrenalectomy.
- ***Thymic tumours*** may press on the trachea, oesophagus and the large veins of the neck, causing hoarseness, cough, dysphagia and cyanosis.
- ***Myasthenia gravis:*** It is a rare autoimmune disease. It is associated in 70% cases of thymoma (tumour of epithelioreticular cells). In myasthenia gravis, antibodies slowly destroy cholinergic receptors from skeletal muscle and cause weakness of muscles. It results in double vision (eye muscles), drooping of eyelid, dysarthria (muscles of throat), and so on (Fig. 8.17).

Histology of Thymus (Plate 8.3)

1. The thymus is surrounded by a thin connective tissue capsule. Thymus is divided into number of incomplete lobules by septa arising from capsule.
2. The thymus has outer darkly stained ***cortex*** and inner lightly stained ***medulla***. Medulla of adjacent lobules is continuous with each other.
3. Medulla shows ***Hassall's corpuscles***: A central pink hyalinised material surrounded by type VI epithelioreticular cells.
4. Epithelioreticular cells (type I-VI): Form meshwork, form blood–thymic barrier, and secrete thymosin and thymopoietin.

Development of Thymus

- Thymus develops from the endoderm of the ventral wing of the third pharyngeal pouch and from the mesenchyme into which the epithelial tubes grow.
- The bilateral primordia of the thymus lose their connections with the pharyngeal wall, come together in the median plane to form bilobed structure which migrates into the superior mediastinum part of the thoracic cavity.
- Thymus continues to grow after birth till puberty, after which it begins to undergo involution. Consequently, it is difficult to recognise in old age, as it is atrophied and replaced by fatty tissue.

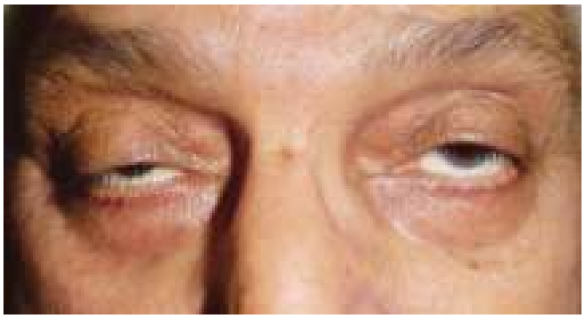
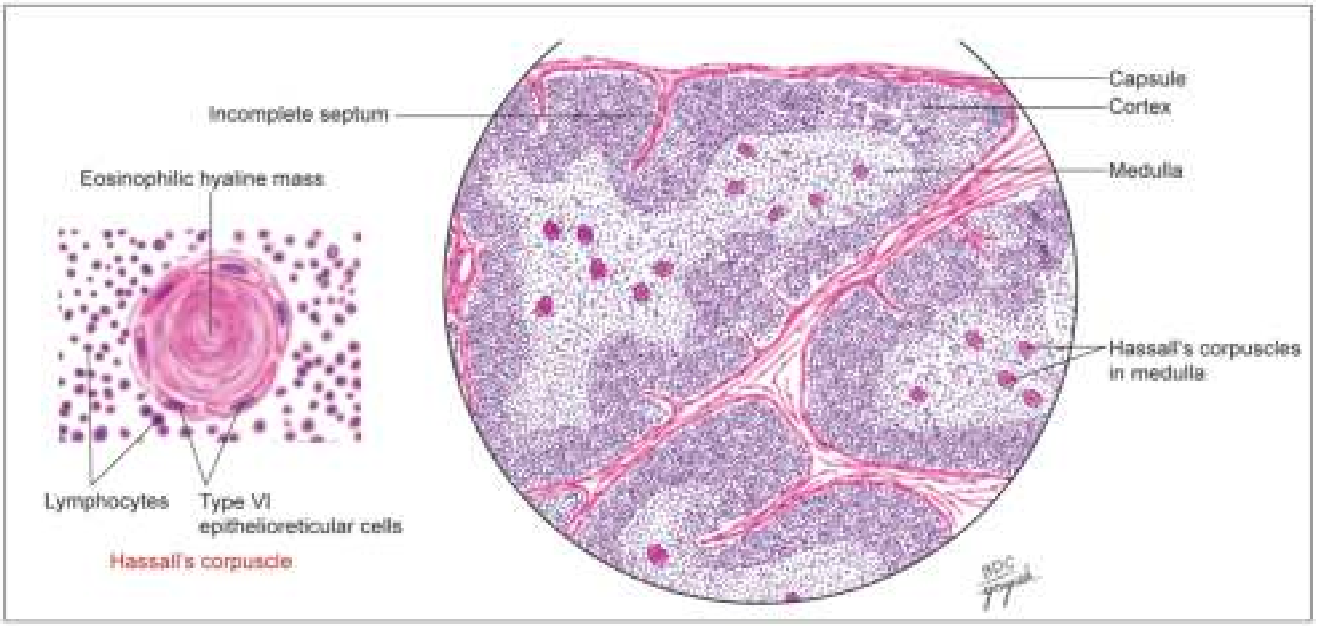


Fig. 8.17: Myasthenia gravis

Plate 8.3: Histology of thymus


Incomplete septum
Eosinophilic hyaline mass
Lymphocytes
Type VI epithelioreticular cells
Hassall's corpuscle
Capsule
Cortex
Medulla
Hassall's corpuscles in medulla

BLOOD VESSELS OF THE NECK

Competency:
AN35.3 Demonstrate and describe the origin, parts, course and branches of subclavian artery.

SUBCLAVIAN ARTERY

This is the principal artery which continues as axillary artery for the upper limb. It also supplies a considerable part of the neck and brain through its branches (Fig. 8.18, Flowchart 8.2).

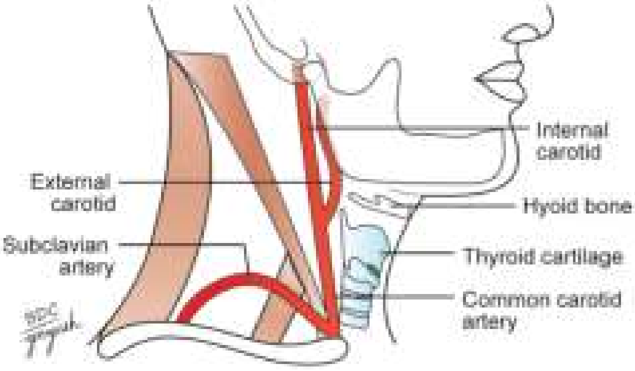

Internal carotid
External carotid
Hyoid bone
Subclavian artery
Thyroid cartilage
Common carotid artery

Fig. 8.18: Origin and course of the subclavian arteries

Beginning (Fig. 8.18)

On the *right side*, it is a branch of the brachiocephalic artery. It arises posterior to the sternoclavicular joint. On the *left side*, it is a branch of the arch of the aorta. It ascends and enters the neck posterior to the left sternoclavicular joint. Both arteries pursue a similar course in the neck.

Course (Figs 8.18 and 8.19)

1. Each artery arches laterally from the sternoclavicular joint to the outer border of the first rib where it ends by becoming continuous with the axillary artery.
2. The scalenus anterior muscle crosses the artery anteriorly and divides it into three parts. The first part is medial, the second part posterior, and the third part lateral to scalenus anterior.

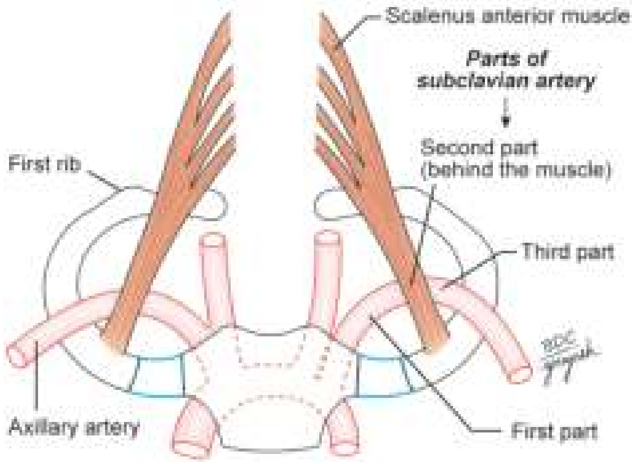

Scalenus anterior muscle
Parts of subclavian artery
Second part (behind the muscle)
First rib
Third part
Axillary artery
First part

Fig. 8.19: Course of subclavian and carotid arteries

Relations of the First Part (Fig. 8.20)

Anterior

Immediate relations from medial to lateral side are:

1. Common carotid artery
2. Vagus
3. Internal jugular vein
4. The sternothyroid and the sternohyoid muscles
5. Sternocleidomastoid

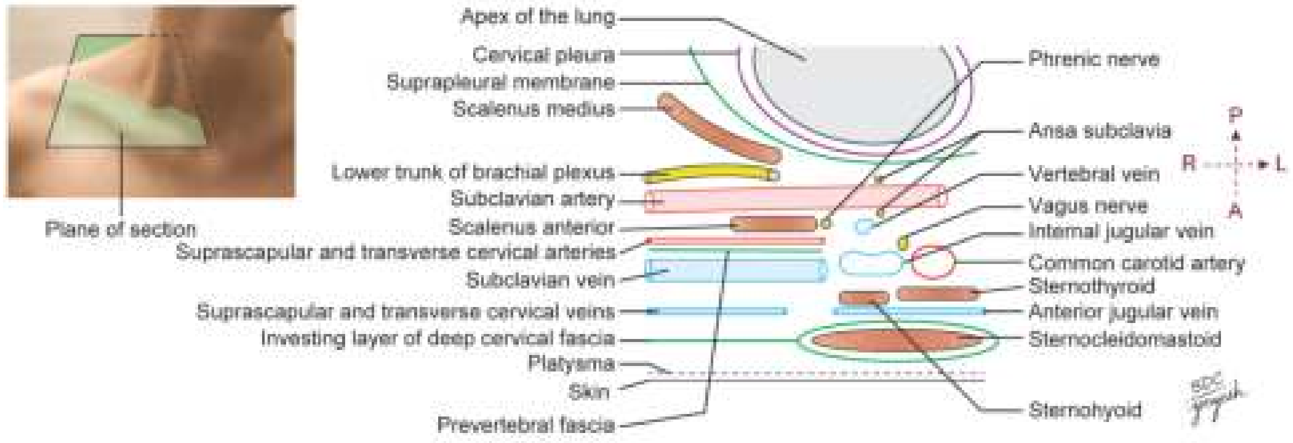
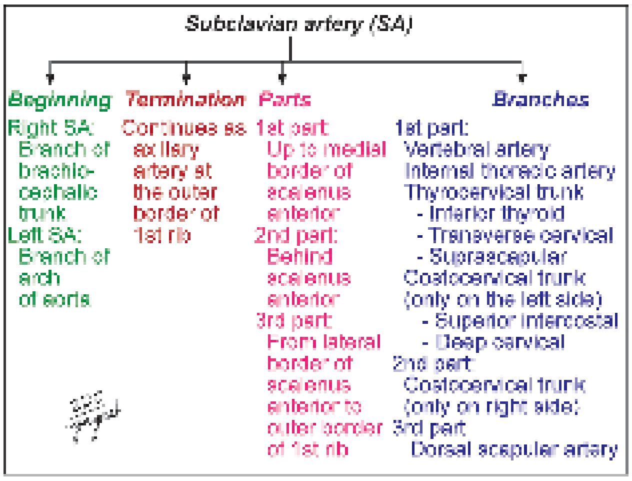

Apex of the lung
Cervical pleura
Suprapleural membrane
Scalenus medius
Lower trunk of brachial plexus
Subclavian artery
Scalenus anterior
Suprascapular and transverse cervical arteries
Subclavian vein
Suprascapular and transverse cervical veins
Investing layer of deep cervical fascia
Platysma
Skin
Prevertebral fascia
Plane of section
Phrenic nerve
Ansa subclavia
Vertebral vein
Vagus nerve
Internal jugular vein
Common carotid artery
Sternothyroid
Anterior jugular vein
Sternocleidomastoid
Sternohyoid
P
R
L
A

Fig. 8.20: Schematic diagram to show the relations of right subclavian artery

Flowchart 8.2: Subclavian artery (SA)


Subclavian artery (SA)
Beginning
Termination
Parts
Branches
Right SA:
Branch of
brachio-
cephalic
trunk
Left SA:
Branch of
arch
of aorta
Continues as
axillary
artery at
the outer
border of
1st rib
1st part
Up to medial
border of
scalenus
anterior
2nd part:
Behind
scalenus
anterior
3rd part
From lateral
border of
scalenus
anterior to
outer border
of 1st rib
1st part:
Vertebral artery
Internal thoracic artery
Thyrocervical trunk
- Inferior thyroid
- Transverse cervical
- Suprascapular
Costocervical trunk
(only on the left side)
- Superior intercostal
- Deep cervical
2nd part
Costocervical trunk
(only on right side)
3rd part
Dorsal scapular artery

Posterior (*Posteroinferior*)

1. Suprapleural membrane
2. Cervical pleura
3. Apex of lung

Relations of the Second Part

Anterior

1. Scalenus anterior
2. Right phrenic nerve deep to the prevertebral fascia
3. Sternocleidomastoid

Posterior (*Posteroinferior*)

1. Suprapleural membrane
2. Cervical pleura
3. Apex of lung

Superior

Upper and middle trunks of the brachial plexus.

Relations of the Third Part

Anterior

1. Middle 1/3rd of the clavicle
2. The posterior border of the sternocleidomastoid

Posterior (*Posteroinferior*)

1. Scalenus medius
2. Lower trunk of brachial plexus
3. Suprapleural membrane
4. Cervical pleura
5. Apex of lung.

Superior

Upper and middle trunks of brachial plexus.

Inferior

First rib.

Branches (Figs 8.21 and 8.22)

From the first part

1. Vertebral artery
2. Internal thoracic artery
3. Thyrocervical trunk, which divides into three branches (Flowchart 8.3):
    a. Inferior thyroid
    b. Suprascapular
    c. Transverse cervical arteries.
4. Costocervical trunk, which divides into two branches (Flowchart 8.3):
    a. Superior intercostal
    b. Deep cervical arteries.

    This artery comes *from second part* on the right side.

From the third part: Dorsal scapular artery—occasionally.

Vertebral Artery

Vertebral artery is the 1st and largest branch of the 1st part of the subclavian artery. It runs a long course and ends in the cranial cavity by supplying the brain. It is divided into four parts. Its details are described in *see* Chapter 9, page 163.

Internal Thoracic Artery

Internal thoracic artery arises from the inferior aspect of the 1st part of the subclavian artery opposite the origin of the thyrocervical trunk. The origin lies near the medial border of the scalenus anterior. The artery

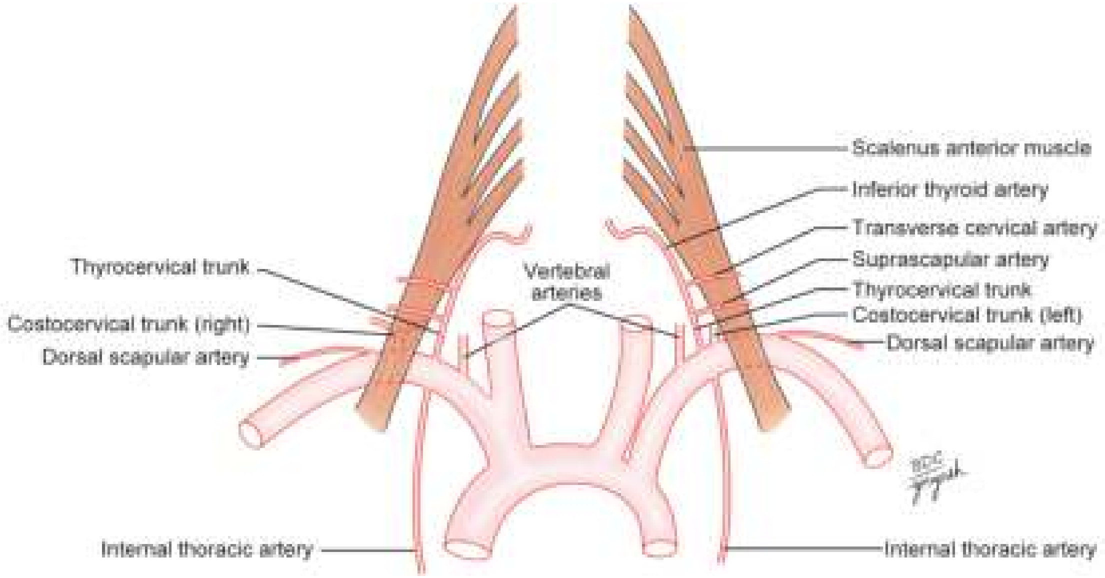

Scalenus anterior muscle
Inferior thyroid artery
Transverse cervical artery
Suprascapular artery
Thyrocervical trunk
Costocervical trunk (left)
Dorsal scapular artery
Thyrocervical trunk
Costocervical trunk (right)
Dorsal scapular artery
Vertebral arteries
Internal thoracic artery
Internal thoracic artery

Fig. 8.21: Branches of the subclavian artery

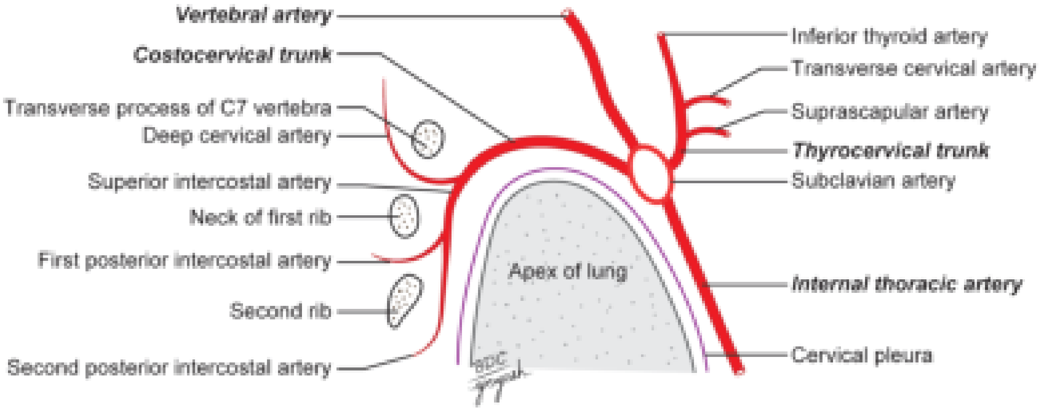
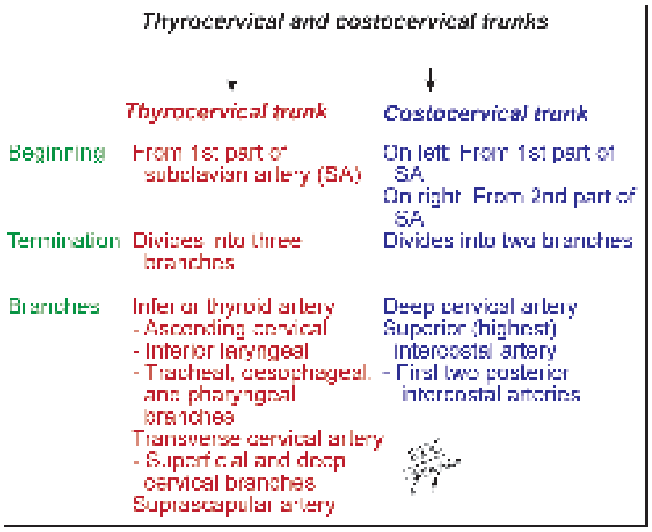

Vertebral artery
Costocervical trunk
Transverse process of C7 vertebra
Deep cervical artery
Superior intercostal artery
Neck of first rib
First posterior intercostal artery
Second rib
Second posterior intercostal artery
Inferior thyroid artery
Transverse cervical artery
Suprascapular artery
Thyrocervical trunk
Subclavian artery
Apex of lung
Internal thoracic artery
Cervical pleura

Fig. 8.22: Branches of the subclavian artery. Note that the branches actually arise at different levels, but are shown at same level schematically

Flowchart 8.3: Thyrocervical and costocervical trunks



Thyrocervical and costocervical trunks

	Thyrocervical trunk	*Costocervical trunk*
Beginning	From 1st part of subclavian artery (SA)	On left: From 1st part of SA On right: From 2nd part of SA
Termination	Divides into three branches	Divides into two branches
Branches	Inferior thyroid artery - Ascending cervical - Inferior laryngeal - Tracheal, oesophageal, and pharyngeal branches Transverse cervical artery - Superficial and deep cervical branches Suprascapular artery	Deep cervical artery Superior (highest) intercostal artery - First two posterior intercostal arteries

runs downwards and medially in front of the cervical pleura. The artery enters the thorax by passing behind the 1st costal cartilage and runs till 6th intercostal space where it ends by dividing into superior epigastric and musculophrenic arteries (For details, *see* Chapter 14, *BD Chaurasia's Human Anatomy, Volume 1*).

Thyrocervical Trunk

Thyrocervical trunk is a short, wide vessel that arises from the front of the 1st part of the subclavian artery (Flowchart 8.3). It almost immediately divides into the inferior thyroid, suprascapular and transverse cervical arteries.

Inferior thyroid artery: In addition to glandular branches to the thyroid, it gives:

1. ***Ascending cervical artery*** which runs upwards in front of the transverse processes of cervical vertebrae.
2. ***Inferior laryngeal artery*** which accompanies the recurrent laryngeal nerve, and enters the larynx deep to the lower border of the inferior constrictor.
3. Other branches which supply the pharynx, the trachea, the oesophagus and surrounding muscles.

Suprascapular artery: It runs laterally and downwards, and crosses the scalenus anterior and the phrenic nerve.

It lies behind the internal jugular vein and the sternocleidomastoid. It then crosses the trunks of the brachial plexus and runs in the posterior triangle, behind and parallel with the clavicle, to reach the superior border of the scapula (*see* Fig. 3.16b).

It crosses above the suprascapular ligament and takes part in the anastomoses around the scapula (*see* Chapter 6, *BD Chaurasia's Human Anatomy, Volume 1*).

Transverse cervical artery: It runs laterally above the suprascapular artery (*see* Fig. 3.16b).

It crosses the scalenus anterior and the sternocleidomastoid. It then crosses the brachial plexus and the floor of the posterior triangle to reach the anterior border of trapezius, where it divides into superficial and deep branches. The ***superficial branch*** accompanies the spinal root of accessory nerve till the lower end of the muscle.

The ***deep branch*** passes deep to levator scapulae and takes part in the anastomoses around the scapula.

Note: Sometimes the two branches may arise separately; the superficial from thyrocervical trunk and the deep from the third part of subclavian artery. Then these are named ***superficial cervical*** and ***dorsal scapular arteries***.

Dorsal Scapular Artery

This artery occasionally arises from the 3rd part of subclavian artery.

Note: If transverse cervical does not divide into superficial and deep branches but continues as superficial branch, the distribution of deep branch is taken over by dorsal scapular artery.

Costocervical Trunk

Costocervical trunk arises from the posterior surface of the 2nd part of the subclavian artery on the right side; but from the 1st part of the artery on the left side. It arches backwards over the cervical pleura and divides into the descending superior intercostal and ascending deep cervical arteries at the neck of the 1st rib (Flowchart 8.3).

Superior intercostal artery: It descends in front of the neck of the 1st rib, and divides into the 1st and 2nd posterior intercostal arteries.

Deep cervical artery: It is analogous to the posterior branch of a posterior intercostal artery. It passes backwards between the transverse process of the 7th cervical vertebra and the neck of the 1st rib. It then ascends between the semispinalis capitis and cervicis up to the axis vertebra. It anastomoses with the occipital and vertebral arteries.

Competency:
AN35.9 Describe the clinical features of compression of subclavian artery and lower trunk of brachial plexus by cervical rib.

CLINICAL ANATOMY

- The 3rd part of the subclavian artery can be effectively compressed against the 1st rib after depressing the shoulder. The pressure is applied downwards, backwards, and medially in the angle between the sternocleidomastoid and the clavicle.
- A ***cervical rib*** may compress the subclavian artery, diminishing the radial pulse (Fig. 8.23).
- The right subclavian artery may arise from the descending thoracic aorta. In that case, it passes posterior to the oesophagus which may be compressed and the condition is known as ***dysphagia lusoria***.
- An aneurysm may form in the third part of the subclavian artery. Its pressure on the brachial plexus causes pain, weakness, and numbness in the upper limb.
- Obstruction to the subclavian artery proximal to the origin of vertebral artery may lead to 'stealing of blood from the brain through the opposite vertebral artery'. This may provide necessary blood to the affected side. The nervous symptoms incurred are called '***subclavian steal syndrome***' (Fig. 8.24).

DISSECTION

Identify scalenus anterior muscle in the anteroinferior part of the neck. Subclavian artery gets divided into three parts by this muscle. Identify vertebral, internal thoracic artery and the thyrocervical trunk with its branches arising from the first part of the artery, costocervical arising from 2nd part and either dorsal scapular or none from the third part.

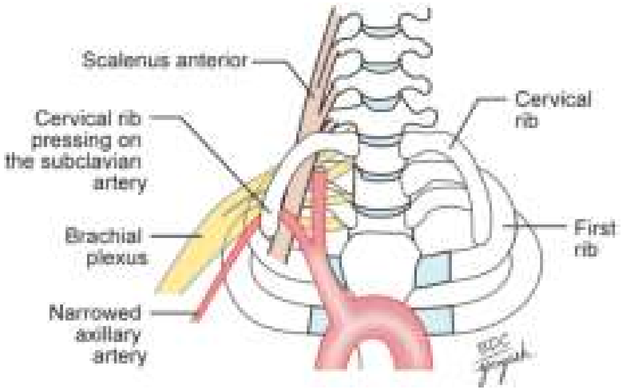


Fig. 8.23: The cervical rib pressing on the subclavian artery narrowing the axillary artery and diminishing the radial pulse

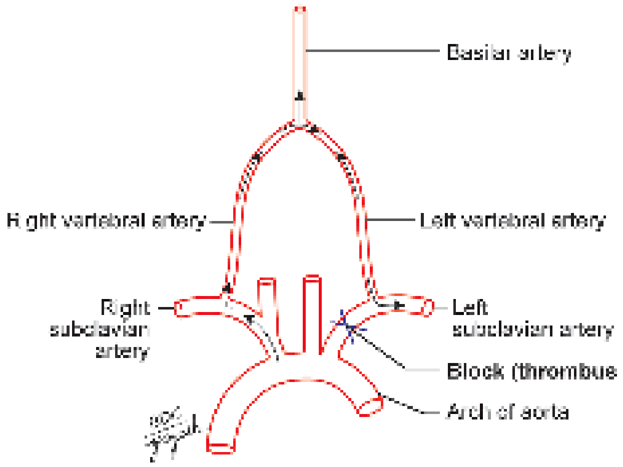


Fig. 8.24: Subclavian steal syndrome

COMMON CAROTID ARTERY

The right common carotid artery arises from the brachiocephalic artery behind the right sternoclavicular joint. The left common carotid artery arises from the arch of aorta in the thoracic cavity. It ascends toward the left sternoclavicular joint to the neck. The common carotid artery is enclosed in the *carotid sheath.*

Course

Common carotid artery begins in the thorax in front of the trachea opposite a point a little to the left of the centre of the manubrium. It ascends to the back of left sternoclavicular joint and enters the neck.

In the neck, both arteries have a similar course. Each artery runs upwards within the carotid sheath, under cover of the anterior border of the sternocleidomastoid. It lies in front of the lower four cervical transverse processes. At the level of the upper border of the thyroid cartilage, the artery ends by dividing into the external and internal carotid arteries.

Relations of the Artery in the Neck (Fig. 8.25)

Anterior Relations

1. The common carotid artery is crossed by the superior belly of omohyoid at the level of cricoid cartilage.
2. Below the omohyoid, the artery is deeply situated, and is covered by:
   a. Sternocleidomastoid
   b. Anterior jugular vein
   c. Sternohyoid
   d. Sternothyroid and the middle thyroid vein.

Posterior Relations

1. Transverse process of vertebrae C4–C7, and the muscles attached to their anterior tubercles (longus colli, longus capitis and scalenus anterior)
2. The inferior thyroid artery crosses medially at the level of the cricoid cartilage
3. Vertebral artery
4. On the left side, the thoracic duct crosses laterally behind the artery at the level of vertebra C7, in front of the vertebral vessels.

Medial Relations

1. Thyroid gland
2. Larynx and pharynx; trachea, oesophagus and recurrent laryngeal nerve.

Lateral Relation

Internal jugular vein.

Posterolateral Relation

Vagus nerve.

CLINICAL ANATOMY

The pulsation of common carotid artery can be felt by compressing against the carotid tubercle, i.e. the anterior tubercle of the transverse process of vertebra C6 which lies at the level of the cricoid cartilage.

DISSECTION

The common carotid artery has been exposed in the carotid triangle. Clean it in its entire course. Identify the internal carotid artery and trace it till it leaves the neck.

Veins

Identify the tributaries of subclavian, internal jugular and brachiocephalic veins.

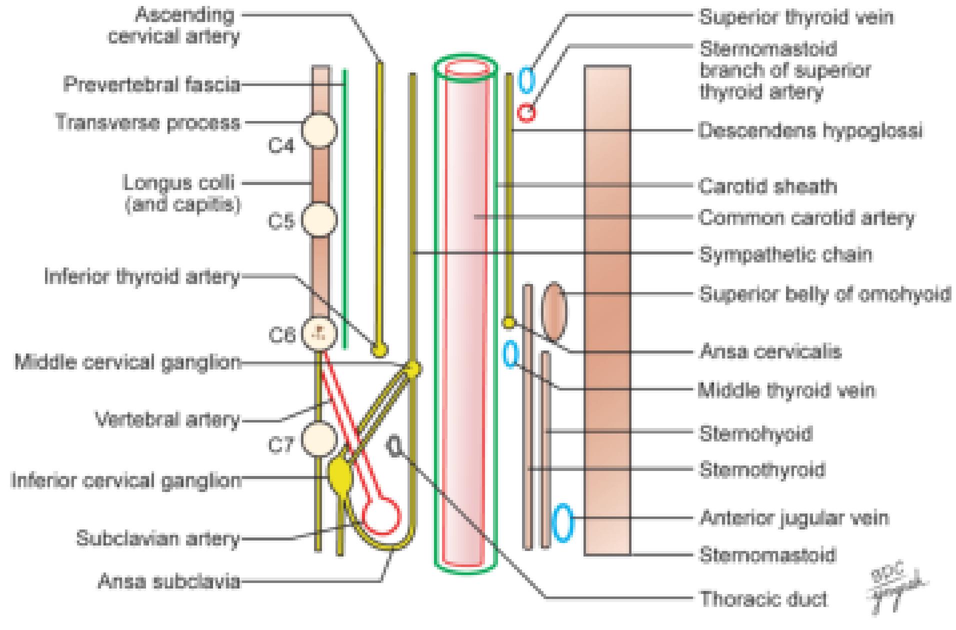

Ascending cervical artery
Prevertebral fascia
Transverse process
C4
Longus colli (and capitis)
C5
Inferior thyroid artery
C6
Middle cervical ganglion
Vertebral artery
C7
Inferior cervical ganglion
Subclavian artery
Ansa subclavia
Superior thyroid vein
Sternomastoid branch of superior thyroid artery
Descendens hypoglossi
Carotid sheath
Common carotid artery
Sympathetic chain
Superior belly of omohyoid
Ansa cervicalis
Middle thyroid vein
Sternohyoid
Sternothyroid
Anterior jugular vein
Sternomastoid
Thoracic duct

Fig. 8.25: Schematic sagittal section showing posterior relations of the common carotid artery

INTERNAL CAROTID ARTERY

The internal carotid artery is one of the two terminal branches of the common carotid artery. It begins at the level of the upper border of the thyroid cartilage opposite the disc between the 3rd and 4th cervical vertebrae and ends inside the cranial cavity by supplying the brain. This is the principal artery of the brain and the eye. It also supplies the related bones and meninges.

For convenience of description, the course of the artery is divided into four parts:

1. Cervical part, in the neck
2. Petrous part, within the petrous temporal bone
3. Cavernous part, within the cavernous sinus
4. Cerebral part in relation to base of the brain.

Cervical Part

1. It ascends vertically in the neck from its origin to the base of the skull to reach the lower end of the carotid canal. This part is enclosed in the carotid sheath (with the internal jugular vein and the vagus nerve)
2. No branches arise from the internal carotid artery in the neck
3. Its initial part usually shows a dilatation, the *carotid sinus* which acts as a baroreceptor
4. The lower part of the artery (in the carotid triangle) is comparatively superficial. The upper part, above the posterior belly of digastric, is deep into the parotid gland, the styloid apparatus, and many other structures.

Relations (Fig. 8.26)

Anterior or superficial

1. In the carotid triangle:
    a. Anterior border of sternocleidomastoid
    b. External carotid artery is anteromedial to it.
2. Above the carotid triangle:
    a. Posterior belly of digastric
    b. Stylohyoid
    c. Stylopharyngeus
    d. Styloid process
    e. Parotid gland with structures within it.

Posterior

1. Superior cervical ganglion
2. Carotid sheath
3. The glossopharyngeal, vagus, accessory and hypoglossal nerves at the base of the skull.

Medial

1. Pharynx
2. The external carotid is anteromedial to it below the parotid.

Lateral

1. Internal jugular vein
2. Temporomandibular joint (at the base of the skull).

Petrous Part

In the carotid canal, the artery first runs upwards and then turns forwards and medially at right angles. It emerges at the apex of the petrous temporal bone, in the posterior wall of the foramen lacerum where it turns upwards and medially.

Cavernous and Cerebral Parts

Cavernous part runs in the cavernous sinus. Cerebral part lies at base of skull and gives ophthalmic, anterior cerebral, middle cerebral, posterior communicating and anterior choroidal arteries.

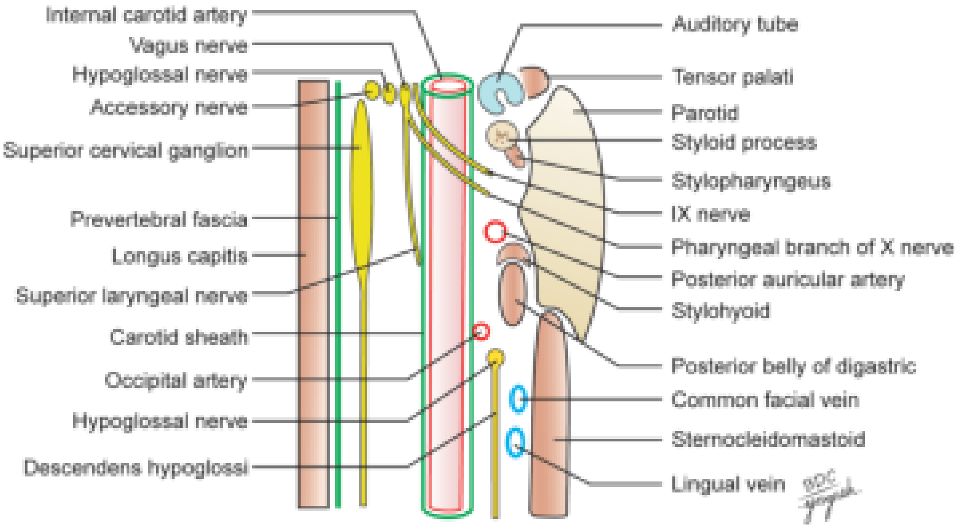
Branches (Fig. 8.27, Flowchart 8.4)

Cervical part

No branch.

Petrous part

1. Caroticotympanic branches
2. Pterygoid branch.



Internal carotid artery
Vagus nerve
Hypoglossal nerve
Accessory nerve
Superior cervical ganglion
Prevertebral fascia
Longus capitis
Superior laryngeal nerve
Carotid sheath
Occipital artery
Hypoglossal nerve
Descendens hypoglossi
Auditory tube
Tensor palati
Parotid
Styloid process
Stylopharyngeus
IX nerve
Pharyngeal branch of X nerve
Posterior auricular artery
Stylohyoid
Posterior belly of digastric
Common facial vein
Sternocleidomastoid
Lingual vein

Fig. 8.26: Schematic sagittal section showing the anterior and posterior relations of the internal carotid artery

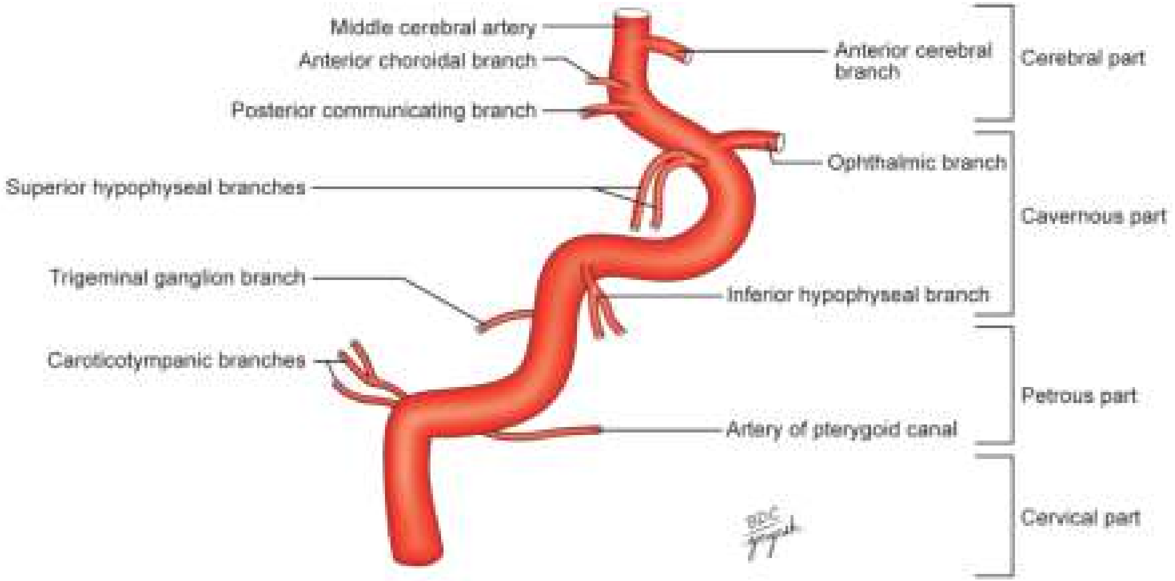
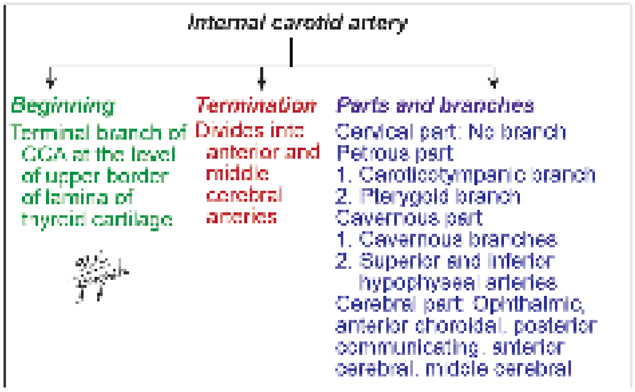

Middle cerebral artery
Anterior choroidal branch
Posterior communicating branch
Superior hypophyseal branches
Trigeminal ganglion branch
Caroticotympanic branches
Anterior cerebral branch
Ophthalmic branch
Inferior hypophyseal branch
Artery of pterygoid canal
Cerebral part
Cavernous part
Petrous part
Cervical part

Fig. 8.27: Branches and parts of the right internal carotid artery

Flowchart 8.4: Internal carotid artery


Internal carotid artery
Beginning
Terminal branch of CCA at the level of upper border of lamina of thyroid cartilage
Termination
Divides into anterior and middle cerebral arteries
Parts and branches
Cervical part: No branch
Petrous part
1. Caroticotympanic branch
2. Pterygoid branch
Cavernous part
1. Cavernous branches
2. Superior and inferior hypophyseal arteries
Cerebral part: Ophthalmic, anterior choroidal, posterior communicating, anterior cerebral, middle cerebral

(CCA: Common carotid artery)

Cavernous part

1. Cavernous branches
2. Superior and inferior hypophyseal arteries.

Cerebral part

1. Ophthalmic artery
2. Anterior choroidal artery
3. Posterior communicating artery
4. Anterior cerebral artery
5. Middle cerebral artery.

Competency:

AN35.4 Describe and demonstrate origin, course, relations, tributaries and termination of internal jugular and brachiocephalic veins.

INTERNAL JUGULAR VEIN

It is a direct continuation of the sigmoid sinus. It begins at the jugular foramen and ends behind the sternal end of the clavicle by joining the subclavian vein to form the brachiocephalic vein (Fig. 8.28, Flowchart 8.5).

Features

1. *Superior bulb:* It is a dilatation at the beginning of the internal jugular vein. It lies in the *jugular fossa* of the temporal bone.
2. *Inferior bulb:* It is a dilation near the termination of the internal jugular vein. It lies in the lesser supraclavicular fossa.
3. *Larger right internal jugular vein*: The right IJV is larger than the left as it is a direct continuation of larger right sigmoid sinus (larger superior sagittal sinus). The left IJV is a continuation of smaller left sigmoid sinus (smaller inferior sagittal sinus).
4. *Enclosed within the carotid sheath*: IJV, carotid arteries, and vagus nerve are enclosed with the carotid sheath which is thinner around the vein.
5. *Lymph nodes*: The deep cervical nodes lie along the entire course of IJV.
6. *Lymphatic duct*: At *jugulo-subclavian angle* on the left, the thoracic duct opens, whereas, on the right, the *right lymphatic duct* opens.

Relations

Superficial

1. Sternocleidomastoid
2. Posterior belly of digastric
3. Superior belly of omohyoid
4. Parotid gland
5. Styloid process
6. The internal carotid artery, and the glossopharyngeal, vagus, accessory and hypoglossal cranial nerves (at the base of skull).

Posterior

1. Transverse process of atlas
2. Cervical plexus
3. Scalenus anterior
4. First part of subclavian artery.

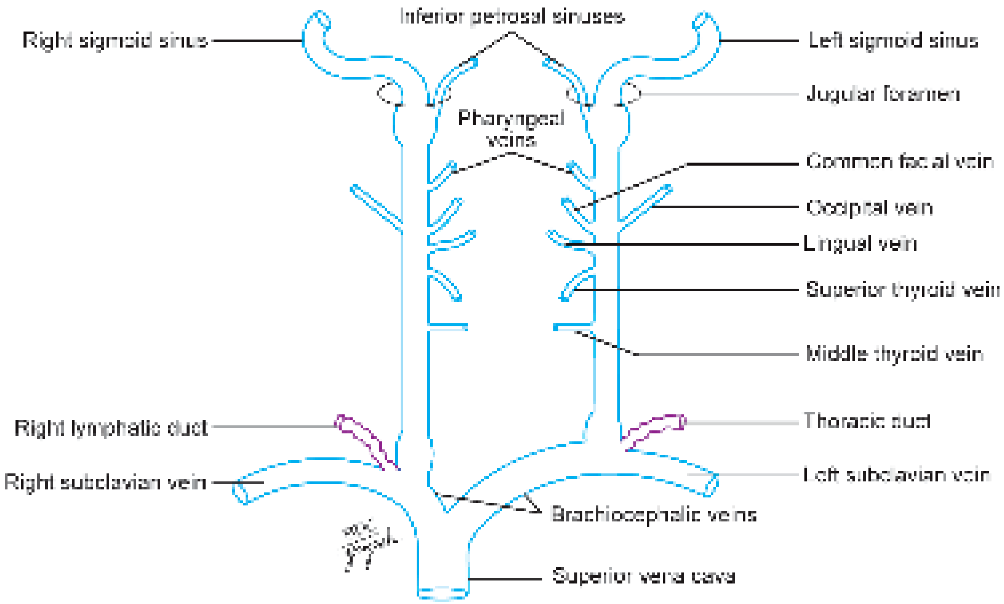
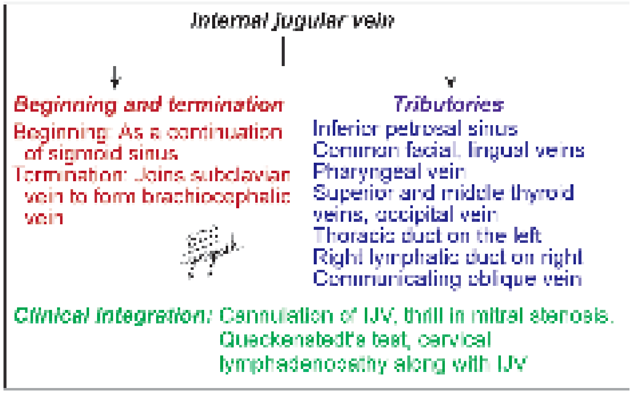

Inferior petrosal sinuses
Right sigmoid sinus
Left sigmoid sinus
Jugular foramen
Pharyngeal veins
Common facial vein
Occipital vein
Lingual vein
Superior thyroid vein
Middle thyroid vein
Thoracic duct
Right lymphatic duct
Right subclavian vein
Left subclavian vein
Brachiocephalic veins
Superior vena cava

Fig. 8.28: Internal jugular veins

Flowchart 8.5: Internal jugular vein (IJV)



Internal jugular vein

Beginning and termination

Beginning: As a continuation of sigmoid sinus

Termination: Joins subclavian vein to form brachiocephalic vein

Tributaries

Inferior petrosal sinus
Common facial, lingual veins
Pharyngeal vein
Superior and middle thyroid veins, occipital vein
Thoracic duct on the left
Right lymphatic duct on right
Communicating oblique vein

Clinical integration: Cannulation of IJV, thrill in mitral stenosis, Queckenstedt's test, cervical lymphadenopathy along with IJV

Medial

1. Internal carotid artery
2. Common carotid artery
3. Vagus nerve.

Tributaries

1. Inferior petrosal sinus
2. Common facial vein
3. Lingual vein
4. Pharyngeal veins
5. Superior thyroid vein
6. Middle thyroid vein.

Note: In the middle of the neck, the internal jugular vein may communicate with the external jugular vein through the oblique jugular vein which runs across the anterior border of the sternocleidomastoid.

[*Mnemonics: **Tributaries of Internal Jugular Vein:*** **"M**edical **S**chools **L**et **C**onfident **P**eople **I**n**"** From inferior to superior: **M**iddle thyroid; **C**ommon facial; **S**uperior thyroid; **P**haryngeal; **L**ingual **I**nferior petrosal sinus]

CLINICAL ANATOMY

- ***Cannulation of IJV:*** It can be cannulation through the apex of the lesser supraclavicular triangle that lies between the two heads of the sternocleidomastoid muscle. The needle should be directed backward and upward to avoid the puncture of cervical pleura. If it is punctured, it will lead to pneumothorax.
- ***Thrill*** can be felt sometimes at the lesser supraclavicular triangle during atrial systole, especially in cases of mitral stenosis.
- ***Queckenstedt's test:*** Compression of the internal jugular veins increases the rate of CSF flow during lumbar puncture. Block in the spinal subarachnoid space result in the failure of this increase of CSF flow.
- ***Cervical lymphadenopathy and IJV:*** The IJV is a surgical guide for removal of cervical lymph nodes. In malignant and tubercular lymphadenopathy, the lymph nodes often adhere to IJV and resection of such lymph nodes becomes difficult. It may require the removal of a segment of IJV.

SUBCLAVIAN VEIN

Course

It is a continuation of the axillary vein. It begins at the outer border of the first rib, and ends at the medial border of the scalenus anterior by joining the internal jugular vein to form the brachiocephalic vein (Fig. 8.29).

It lies:

1. In front of the subclavian artery, the scalenus anterior and the right phrenic nerve.
2. Behind the clavicle and the subclavius.
3. Above the first rib and pleura.

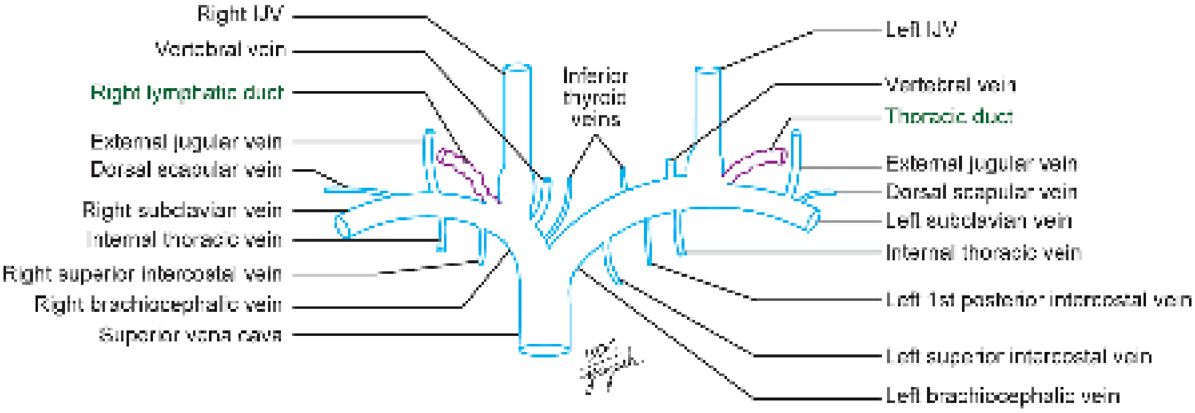

Right IJV
Vertebral vein
Right lymphatic duct
External jugular vein
Dorsal scapular vein
Right subclavian vein
Internal thoracic vein
Right superior intercostal vein
Right brachiocephalic vein
Superior vena cava
Inferior thyroid veins
Left IJV
Vertebral vein
Thoracic duct
External jugular vein
Dorsal scapular vein
Left subclavian vein
Internal thoracic vein
Left 1st posterior intercostal vein
Left superior intercostal vein
Left brachiocephalic vein

Fig. 8.29: Subclavian and brachiocephalic veins

Its tributaries are:

1. External jugular vein
2. Dorsal scapular vein
3. Thoracic duct on the left side
4. Right lymphatic duct on the right side.

BRACHIOCEPHALIC VEIN

1. The right brachiocephalic vein (2.5 cm long) is shorter than the left (6 cm long) (Fig. 8.29).
2. Each vein is formed behind the sternoclavicular joint, by the union of the internal jugular vein and the subclavian vein.
3. The right vein runs vertically downwards. The left vein runs obliquely downwards and to the right behind the upper half of the manubrium sterni. The two brachiocephalic veins unite at the lower border of the right first costal cartilage to form the superior vena cava.

Tributaries

The *tributaries* correspond to the branches of the 1st part of the subclavian artery. These are as follows:

Right brachiocephalic:

1. Vertebral
2. Internal thoracic
3. First posterior intercostal
4. Right lymphatic duct.

Left brachiocephalic:

1. Vertebral
2. Internal thoracic
3. Inferior thyroid on both sides
4. First posterior intercostal
5. Left superior intercostal
6. Thymic and pericardial veins
7. Thoracic duct.

Competency:
AN35.7 Describe the course and branches of IX, X, XI and XII nerve in the neck.

NERVES OF THE NECK

GLOSSOPHARYNGEAL NERVE—IX NERVE

Glossopharyngeal nerve exits the cranial cavity via anterior part of jugular foramen.

Course (Fig. 8.30)

1. It runs between internal carotid artery and internal jugular vein, lying deep to the styloid process and muscles attached to the process.
2. Then it courses between internal carotid and external carotid arteries, where it curves around the lateral border of stylopharyngeus muscle.
3. As it reaches submandibular region, it passes deep to hyoglossus muscle to reach the area of palatine tonsil and base of the tongue.

Branches (Figs 8.31a and b)

1. Tympanic branch courses through middle ear and gives secretomotor root to otic ganglion.
2. Carotid branch for carotid body and carotid sinus.
3. Muscular for stylopharyngeus muscle.
4. Carries taste from vallate papillae of tongue.
5. Carries general sensations from posterior one-third of tongue and palatine tonsil.
6. Branch to pharyngeal plexus.

VAGUS NERVE—X NERVE

Vagus leaves the cranial cavity through jugular foramen lying posterior to IX nerve. Soon it is joined course by cranial root of XI nerve. In the neck, the nerve lies in the carotid sheath, medial to internal jugular vein and posterior to internal carotid and common carotid arteries.

Then it passes through thorax and abdomen.

Branches in Neck

1. Meningeal
2. Auricular
3. Pharyngeal for most muscles of soft palate 4 out of 5 and pharynx 5 out 6, carotid for carotid body

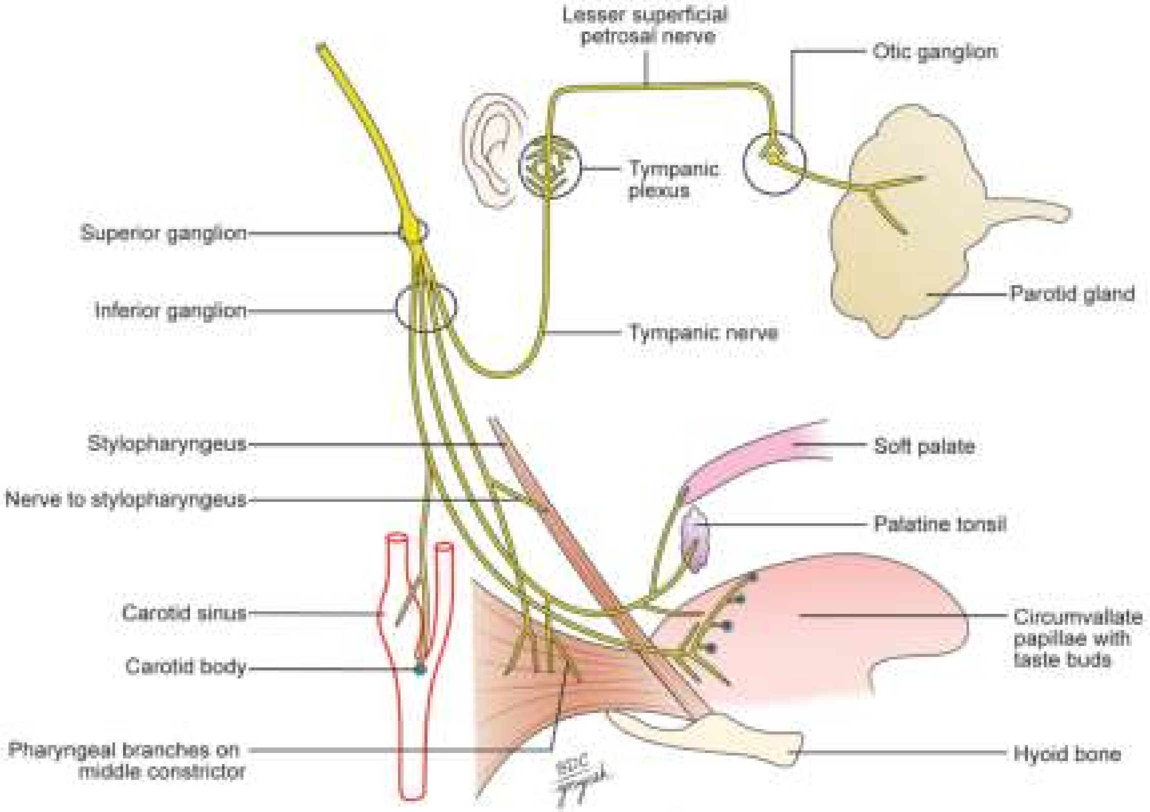
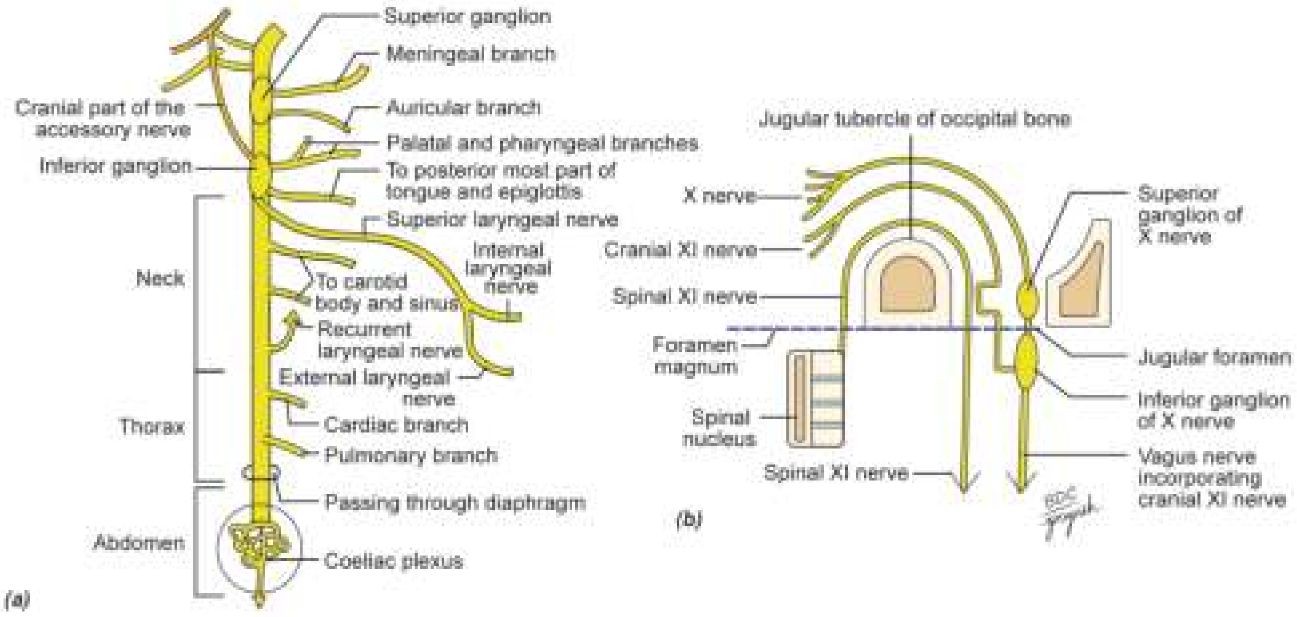

Lesser superficial petrosal nerve
Otic ganglion
Tympanic plexus
Superior ganglion
Parotid gland
Inferior ganglion
Tympanic nerve
Stylopharyngeus
Soft palate
Nerve to stylopharyngeus
Palatine tonsil
Carotid sinus
Circumvallate papillae with taste buds
Carotid body
Pharyngeal branches on middle constrictor
Hyoid bone

Fig. 8.30: Distribution of glossopharyngeal nerve


Superior ganglion
Meningeal branch
Cranial part of the accessory nerve
Auricular branch
Palatal and pharyngeal branches
Inferior ganglion
To posterior most part of tongue and epiglottis
Superior laryngeal nerve
Internal laryngeal nerve
Neck
To carotid body and sinus
Recurrent laryngeal nerve
External laryngeal nerve
Thorax
Cardiac branch
Pulmonary branch
Passing through diaphragm
Abdomen
Coeliac plexus
(a)
Jugular tubercle of occipital bone
X nerve
Superior ganglion of X nerve
Cranial XI nerve
Spinal XI nerve
Foramen magnum
Jugular foramen
Inferior ganglion of X nerve
Spinal nucleus
Spinal XI nerve
Vagus nerve incorporating cranial XI nerve
(b)

Figs 8.31a and b: (a) Branches of vagus nerve and (b) course of accessory nerve

and carotid sinus, superior laryngeal gives internal laryngeal for mucous membrane of larynx and external laryngeal for cricothyroid muscle.

4. Right recurrent laryngeal is given off in neck while left one is given off in thorax. The nerves supply all intrinsic muscles of larynx and sensory branches to mucous membrane of larynx below vocal cords.
5. Cardiac branches for deep cardiac plexus.

ACCESSORY NERVE—XI NERVE

This nerve also leaves the cranial cavity through the jugular foramen. It is made up of a cranial root and a spinal root. The two roots join in jugular foramen, but again separate as it pass out of the foramen. Cranial root joins X nerve and gets distributed with it for 4 out of 5 palatal muscles, 5 out of 6 pharyngeal muscles and all laryngeal muscles. The spinal root descends between internal jugular vein and internal carotid artery for some distance. It then lies superficial to internal jugular vein to reach anterior border of sternocleidomastoid muscle. It enters the muscle, supplies it and leaves the muscle at its posterior border a little above its middle.

Then it passes downwards and backwards in the posterior triangle of neck. Finally, it leaves posterior triangle by passing deep to trapezius.

Thus the spinal root of XI nerve supplies: Sternocleidomastoid and trapezius muscles.

Details can be read from Chapter 6, *BD Chaurasia's Human Anatomy*, *Volume 4*.

DISSECTION

The course of IX–XI cranial nerves has been seen in different chapters. Now trace these nerves and their branches.

The sympathetic trunk has been identified as lying posteromedial to the carotid sheath. Trace it upwards and downwards and locate the three cervical ganglia.

Dissect the formation and branches of the cervical plexus. Identify the phrenic nerve on the surface of scalenus anterior muscle behind the prevertebral fascia.

Competency:
AN35.6 Describe and demonstrate the extent, formation, relation and branches of cervical sympathetic chain.

CERVICAL PART OF SYMPATHETIC TRUNK

The cervical parts of the right and left sympathetic trunks are situated one on each side of the cervical part of the vertebral column, behind the carotid sheath (common carotid and internal carotid arteries) and in front of the prevertebral fascia (Fig. 8.32).

Formation

There are *no white rami communicantes* (i.e. incoming root) in the neck and this part of the trunk is formed by fibres that emerge from segments T1 to T4 of the spinal cord, and then ascend into the neck. Grey rami communicantes (i.e. outgoing roots) are present.

Relations

Anterior

1. Internal carotid artery
2. Common carotid artery
3. Carotid sheath
4. Inferior thyroid artery.

Posterior

1. Prevertebral fascia
2. Longus capitis and cervicis muscles
3. Transverse processes of the lower six cervical vertebrae.

GANGLIA

Theoretically, there should be eight sympathetic ganglia corresponding to the eight cervical nerves, but due to fusion, there are only three ganglia—superior, middle and inferior.

Superior Cervical Ganglion

Size and Shape

This is the largest of the three ganglia. It is spindle-shaped, and about 2.5 cm long.

Situation and Formation

It lies just below the skull, opposite the second and third cervical vertebrae, behind the carotid sheath and in front of the prevertebral fascia (longus capitis). It is formed by fusion of the upper 4 cervical ganglia.

Communications: With cranial nerves IX, X and XII, and with the external and recurrent laryngeal nerves.

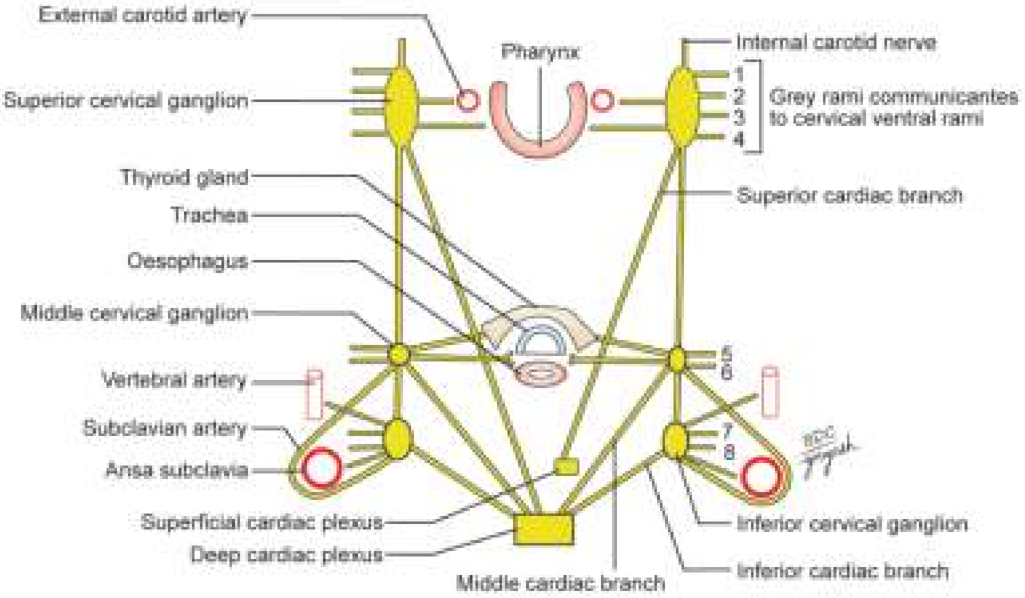

External carotid artery
Superior cervical ganglion
Thyroid gland
Trachea
Oesophagus
Middle cervical ganglion
Vertebral artery
Subclavian artery
Ansa subclavia
Superficial cardiac plexus
Deep cardiac plexus
Middle cardiac branch
Pharynx
Internal carotid nerve
1
2
3
4
Grey rami communicantes to cervical ventral rami
Superior cardiac branch
5
6
7
8
Inferior cervical ganglion
Inferior cardiac branch

Fig. 8.32: The cervical sympathetic trunks and their branches

Branches

1. *Grey rami communicantes* to ventral primary rami of upper four cervical nerves.
2. *Pharyngeal branches* to carotid body and pharyngeal plexus.
3. *Cardiac branches*: Right cardiac branches join the deep cardiac plexus, whereas left cardiac branches join the superficial cardiac plexus.
4. External carotid branches form plexus around the external carotid artery. Some of these fibres pass through the otic and submandibular ganglia.
5. Ascending fibres form the internal carotid nerve or plexus around the internal carotid artery. This plexus gives rise to:
   a. *Caroticotympanic nerve* that enters middle ear and forms tympanic plexus along with the branch of glossopharyngeal nerve.
   b. *Deep petrosal nerve* joins the greater petrosal nerve to form *nerve to pterygoid canal*. Some of these fibres supply dilator pupillae through ciliary ganglion and Müller's muscle.
   c. *Nervus conarii* pass through the tentorium cerebelli to supply the pineal glands.
   d. Terminal branches accompany the branches of internal carotid artery.

Middle Cervical Ganglion

Size and Shape

This ganglion is very small. It may be divided into 2 to 3 smaller parts or may be absent.

Situation

It lies in the lower part of the neck, in front of vertebra C6 just above the inferior thyroid artery, behind the carotid sheath.

Formation

It is formed by fusion of the fifth and sixth cervical ganglia connections. It is connected with the inferior cervical ganglion directly, and also through a loop that winds around the subclavian artery. This loop is called the ansa subclavia.

Branches

1. Grey rami communicantes are given to the ventral rami of the 5th and 6th cervical nerves.
2. *Thyroid branches* accompany the inferior thyroid artery to the thyroid gland. They also supply the parathyroid glands.
3. Tracheal and oesophageal branches.
4. The *middle cervical cardiac branch* is the largest of the sympathetic cardiac branches. It goes to the deep cardiac plexus.

Inferior Cervical Ganglion

Size, Shape and Formation

It is formed by fusion of 7th and 8th cervical ganglia. This is often fused with the first thoracic ganglion and is then known as the *cervicothoracic ganglion* or *stellate ganglion* because it is star-shaped.

It is situated between the transverse process of vertebra C7 and the neck of the first rib. It lies behind the vertebral artery, and in front of ramus of spinal nerve C8. *A cervicothoracic ganglion extends in front of the neck of the first rib.*

Branches

1. *Grey rami communicantes* are given to the ventral rami of nerves C7 and C8.
2. *Vertebral branches* form a plexus around the vertebral artery.
3. *Subclavian branches* form a plexus around the subclavian artery. This plexus is joined by branches from the ansa subclavia.
4. An *inferior cervical cardiac branch* goes to the deep cardiac plexus.

The branches of the cervical sympathetic ganglia are listed in Table 8.1.

Competency:
AN31.3 Describe anatomical basis of Horner's syndrome.

CLINICAL ANATOMY

- The head and neck are supplied by sympathetic nerves arising from the upper four thoracic segments of the spinal cord. Most of these preganglionic fibres pass through the stellate ganglion to relay in the superior cervical ganglion.
- Injury to cervical sympathetic trunk produces Horner's syndrome. It is characterized by:
  a. Ptosis—drooping of the upper eyelid.
  b. Miosis—constriction of the pupil.
  c. Anhydrosis—loss of sweating on that side of the face.
  d. Enophthalmos—retraction of the eyeball.
  e. Loss of the ciliospinal reflex—pinching the skin on the nape of the neck does not produce dilatation of the pupil (which normally takes place).
- Horner's syndrome can also be caused by a lesion within the central nervous system anywhere at or above the first thoracic segment of the spinal cord involving sympathetic fibres (Fig. 8.33).

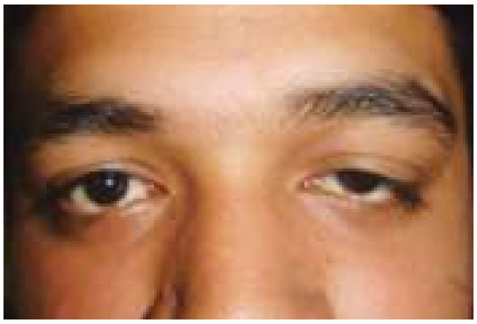


Fig. 8.33: Horner's syndrome on left side

TABLE 8.1: Branches of cervical sympathetic ganglia

	Superior cervical ganglion	*Middle cervical ganglion*	*Inferior cervical ganglion*
Arterial branches	• Along internal carotid artery is internal carotid nerve which gives deep petrosal, nerve to Müller's muscle, to dilator pupillae, to pineal gland • Along common carotid and external carotid arteries for all 3 salivary glands	Along inferior thyroid artery	Along subclavian and vertebral arteries
Grey rami communicantes	Along 1–4 cervical nerves	Along 5 and 6 cervical nerves	Along 7 and 8 cervical nerves
Along cranial nerves	Along cranial nerves IX, X, XI and XII	—	—
Visceral branches	Pharynx, cardiac	Thyroid, cardiac	Cardiac

Competencies:

AN28.5 Describe cervical lymph nodes and lymphatic drainage of head, face and neck.

AN35.5 Describe and demonstrate extent, drainage and applied anatomy of cervical lymph nodes.

LYMPHATIC DRAINAGE OF HEAD AND NECK

Lymph nodes in head and neck are as follows:

1. Superficial group
2. Deep group
3. Deepest group.

Superficial Group (Fig. 8.34)

Buccal and Mandibular Nodes

The buccal node lies on the buccinator, and the mandibular node at the lower border of the mandible near the anteroinferior angle of the masseter, in close relation to the marginal mandibular branch of the facial nerve. They drain part of the cheek and the lower eyelid. Their efferents pass to the anterosuperior group of deep cervical nodes.

Preauricular Nodes

Drain parotid gland, temporal region, middle ear, etc.

Postauricular (Mastoid) Nodes

The postauricular nodes lie on the mastoid process, superficial to the sternocleidomastoid and deep to the auricularis posterior. They drain a strip of scalp just above and behind the auricle, the upper half of the medial surface and margin of the auricle, and the posterior wall of the external acoustic meatus. Their efferents pass to the posterosuperior group of deep cervical nodes.

Occipital Nodes

The occipital nodes lie at the apex of the posterior triangle superficial to the attachment of the trapezius. They drain the occipital region of the scalp. Their efferents pass to the supraclavicular members of the posteroinferior group of deep cervical nodes.

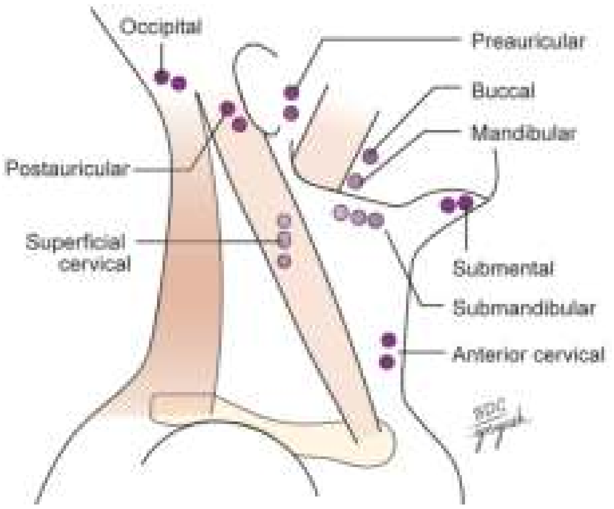


Fig. 8.34: Superficial lymph nodes of the neck

Anterior Superficial Cervical Nodes

The anterior cervical nodes lie along the *anterior jugular vein* and are unimportant. The suprasternal lymph node is a member of this group. They drain the skin of the anterior part of the neck below the hyoid bone. Their efferents pass to the deep cervical nodes of both sides.

Lateral Superficial Cervical Nodes

The superficial cervical nodes lie along the *external jugular vein* superficial to the sternocleidomastoid. They drain the lobule of the auricle, the floor of the external acoustic meatus, and the skin over the lower parotid region and the angle of the jaw. Their efferents pass around both borders of the muscle to reach the upper and lower deep cervical nodes.

Deep Group

It comprises five levels of lymph nodes (Fig. 8.35).

Submental and Submandibular Nodes

Submental nodes lie deep to the chin. These drain the lymph from tip of tongue and anterior part of floor of mouth. The submandibular nodes drain lateral surface of tongue, lower gums and teeth and central area of forehead. The *submandibular lymph nodes* are clinically

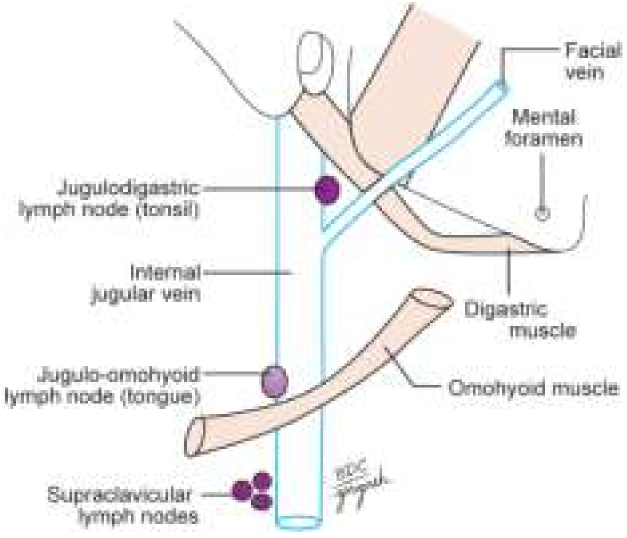

Facial vein
Mental foramen
Jugulodigastric lymph node (tonsil)
Internal jugular vein
Digastric muscle
Jugulo-omohyoid lymph node (tongue)
Omohyoid muscle
Supraclavicular lymph nodes

Fig. 8.35: Deep groups of lymph nodes in the neck

very important because of their wide area of drainage. They are very commonly enlarged. The nodes lie beneath the deep cervical fascia on the surface of the submandibular salivary gland. They drain:

1. Centre of the forehead.
2. Nose with the frontal, maxillary and ethmoidal air sinuses.
3. The inner canthus of the eye.
4. The upper lip and the anterior part of the cheek with the underlying gum and teeth.
5. The outer part of the lower lip with the lower gums and teeth excluding the incisors.
6. The anterior two-thirds of the tongue excluding the tip, and the floor of the mouth. They also receive efferents from the submental lymph nodes.

The *efferents* from the submandibular nodes pass mostly to the jugulo-omohyoid node and partly to the jugulodigastric node. These nodes are situated along the internal jugular vein and are members of the deep cervical chain.

Upper Lateral Nodes around Internal Jugular Vein

The *jugulodigastric node* is a member of this group. It lies below the posterior belly of digastric, between the angle of the mandible and anterior border of the sternocleidomastoid, in the triangle bounded by the posterior belly of digastric, the facial vein and the internal jugular vein. It is the main node draining the *tonsil*.

Middle Lateral Nodes around Internal Jugular Vein

These drain thyroid and parathyroid glands. They receive efferents from prelaryngeal, pretracheal and paratracheal lymph nodes.

Lower Lateral Nodes around Internal Jugular Vein

The *jugulo-omohyoid node* is a group of nodes. It lies just above the intermediate tendon of the omohyoid, under cover of the posterior border of the sternocleidomastoid. It is the main lymph node of the *tongue*.

Lymph Nodes in Posterior Triangle

The lymph nodes are present around the spinal root of accessory nerve.

Efferents of the deep cervical lymph nodes join together to form the *jugular lymph trunks*, one on each side. The left jugular trunk opens into the thoracic duct. The right trunk may open either into the right lymphatic duct, or directly into the angle of junction between the internal jugular and subclavian veins.

Deepest Group

Prelaryngeal and Pretracheal Nodes

The prelaryngeal and pretracheal nodes lie deep to the investing fascia, the prelaryngeal nodes on the cricothyroid membrane, and the pretracheal in front of the trachea below the isthmus of the thyroid gland. They drain the larynx, the trachea and the isthmus of the thyroid. They also receive afferents from the anterior cervical nodes. Their efferents pass to the nearby deep cervical nodes.

Paratracheal Nodes

The paratracheal nodes lie on the sides of the trachea and oesophagus along the recurrent laryngeal nerves. They receive lymph from the oesophagus, the trachea and the larynx, and pass it onto the deep cervical nodes.

Retropharyngeal Nodes

The retropharyngeal nodes lie in front of the prevertebral fascia and behind the buccopharyngeal fascia covering the posterior wall of the pharynx. They extend laterally in front of the lateral mass of the atlas and along the lateral border of the longus capitis. They drain the pharynx, the auditory tube, the soft palate, the posterior part of the hard palate, and the nose. Their efferents pass to the upper lateral group of deep cervical nodes.

Waldeyer's Ring

The ring comprises lingual, palatine, tubal and nasopharyngeal tonsils.

MAIN LYMPH TRUNKS AT THE ROOT OF THE NECK

1. The ***thoracic duct*** is the largest lymph trunk of the body. It begins in the abdomen from the upper end of the cisterna chyli enters the thorax through aortic opening, traverses the thorax, and ends on the left side of the root of the neck by opening into the angle of junction between the left internal jugular vein and the left subclavian vein. Before its termination, it forms an arch at the level of the transverse process of vertebra C7 rising 3 to 4 cm above the clavicle. Apart from its tributaries in the abdomen and thorax, the thoracic duct receives (in the neck):
   a. The left jugular trunk
   b. The left subclavian trunk
   c. The left bronchomediastinal trunk.

   It drains most of the body, except for the right upper limb, the right halves of the head, the neck and the thorax and the superior surface of the liver.

2. **The right *jugular trunk*** drains half of the head and neck.
3. The **right *subclavian trunk*** drains the upper limb.
4. The ***bronchomediastinal trunk*** drains the lung, half of the mediastinum and parts of the anterior walls of the thorax and abdomen.
5. On the right side, the subclavian, jugular and bronchomediastinal trunks unite to form the ***right lymph trunk*** which ends in a manner similar to the thoracic duct.

CLINICAL ANATOMY

- The deep cervical lymph nodes lie on the internal jugular vein. These nodes often become adherent to the vein in malignancy or in tuberculosis. Therefore, during operation on such patients, the vein is also resected. These are examined from behind with the neck slightly flexed.
- Superficial cervical, supraclavicular and lymph nodes of anterior triangle can easily be palpated (Fig. 8.36).
- Chronic infection of the palatine tonsil causes enlargement of jugulodigastric lymph nodes which adhere to the internal jugular vein.
- Painful enlargement of the submandibular lymph nodes is common because infections in tongue, mouth and cheek are quite common. These nodes may be affected by tubercular bacteria.
- The spinal root of accessory nerve may get entangled in the enlarged lymph nodes situated in the posterior triangle of neck. While taking biopsy of the lymph node, one must be careful not to injure the accessory nerve lest trapezius gets damaged.
- The left supraclavicular nodes are called Virchow's lymph nodes. Cancer from stomach and testis may metastasize into these lymph nodes, which may become palpable.
- **Common causes of lymph node enlargement**
  a. *Local causes:* Acute infection, chronic infection, malignancy of any part of the body.
  b. *General causes:* Tuberculosis, secondary syphilis, Hodgkin's disease, lymphatic leukaemia.

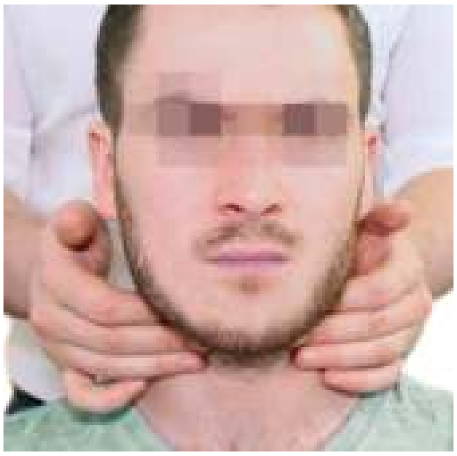


Fig. 8.36: Palpation of the lymph nodes of neck

DISSECTION

Identify the lymph nodes in the submental, the submandibular, the parotid, the mastoid and the occipital regions including the deep cervical nodes. Dissect the main lymph trunk present at the root of the neck.

STYLOID APPARATUS

- The styloid process with its attached structures is called the styloid apparatus.
- The *styloid process* is a long, slender and pointed bony process projecting downwards, forwards and slightly medially from the temporal bone. Its proximal part is enclosed by tympanic plate (tympanohyal). Its distal part gives attachment to muscles and ligaments (stylohyoid). It descends between the external and internal carotid arteries to reach the side of the pharynx. It is interposed between the parotid gland laterally and the internal jugular vein medially.

Attachments of Styloid Process

The structures attached to the process are three muscles and two ligaments:

1. ***Styloglossus** muscle* arises from the anterior surface of the styloid process and is inserted into the side of the tongue.
2. ***Stylopharyngeus** muscle* arises from the medial surface of the base of the styloid process and is inserted on the posterior border of the lamina of the thyroid cartilage.
3. ***Stylohyoid*** extends between posterior surface of styloid process and hyoid bone. It splits at its lower end to enclose the intermediate tendon of digastric muscle.
4. ***Stylomandibular ligament*** is attached laterally to styloid process above and angle of mandible below.
5. ***Stylohyoid ligament*** extends from the tip of the styloid process to the lesser cornua of the hyoid bone.

Features

1. The apparatus is of diverse origin (Fig. 8.37).
   a. Embryologically, styloid process comprises two parts: (i) Tympanohyal is proximal part and is ensheathed by tympanic plate, and (ii) stylohyal is the distal part
   b. The styloid process, the stylohyoid ligament and stylohyoid muscle are derived from the second branchial arch; the stylopharyngeus from the third arch; the styloglossus from occipital myotomes; and the stylomandibular ligament from a part of the deep fascia of neck.
2. The *five attachments resemble the reins of a chariot.* Two of these reins (ligaments) are nonadjustable, whereas the other three (muscles) are adjustable and are controlled each by a separate cranial nerve—seventh, ninth and twelfth nerves.
3. External carotid artery crosses tip of styloid process superficially and pierces stylomandibular ligament.
4. Facial nerve crosses the base of styloid process laterally after it emerges from stylomastoid foramen.

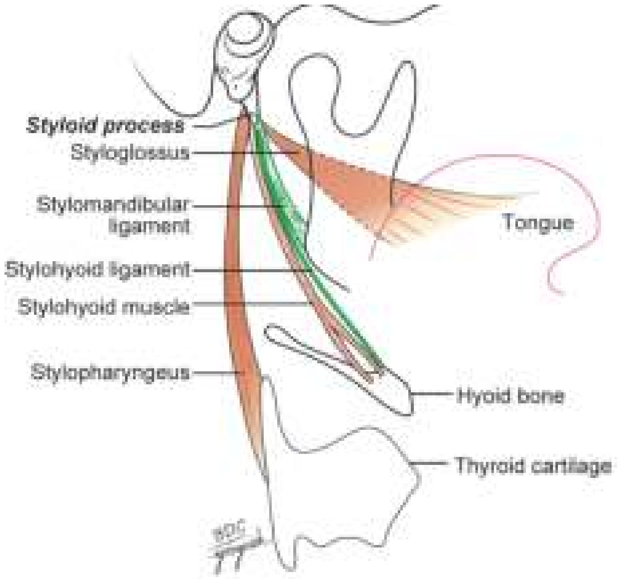

Styloid process
Styloglossus
Stylomandibular ligament
Stylohyoid ligament
Stylohyoid muscle
Stylopharyngeus
Tongue
Hyoid bone
Thyroid cartilage
BDC

Fig. 8.37: The styloid apparatus

DEVELOPMENT OF THE ARTERIES

Brachiocephalic artery	Right aortic sac
Right subclavian artery	Proximal part from the right 4th aortic arch artery and remaining part from right 7th cervical intersegmental artery
Left subclavian artery	Only left 7th cervical intersegmental artery
Common carotid artery	Third aortic arch proximal to external carotid bud
Internal carotid artery	Third aortic arch, distal to the external carotid bud and original dorsal aorta cranial to the attachment of third aortic arch
External carotid artery	Develop as sprout from the third aortic arch
Pulmonary trunk	Part of truncus arteriosus
Arch of aorta	Left aortic sac • Left 4th aortic arch • Left dorsal aorta

Relation to recurrent laryngeal nerve: Recurrent laryngeal is given off from vagi in relation to distal part of 6th arch artery. Since this distal part forms ligamentum arteriosum on left side only, the recurrent laryngeal nerve hooks around this ligamentum in thorax to reach tracheo-oesophageal groove (Fig. 8.38).

On the right side, there is no ligamentum arteriosum, the recurrent laryngeal nerve slips upwards in the neck and hooks around the right subclavian artery to reach the tracheo-oesophageal groove.

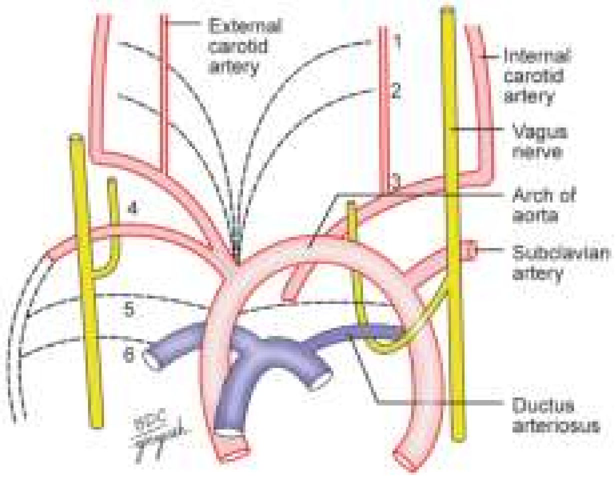

External carotid artery
1
2
3
4
5
6
Internal carotid artery
Vagus nerve
Arch of aorta
Subclavian artery
Ductus arteriosus
BDC

Fig. 8.38: Relation to recurrent laryngeal nerve

VIDEO

Video 3.8 **Thyroid Gland**

Facts to Remember

- Thyroid gland is the largest endocrine and the most vascular gland of the body.
- The most common ectopic site of thyroid gland is within tongue. The most common site of thyroglossal cyst is subhyoid.
- Parathyroid glands lie along the anastomotic channel between posterior branch of superior thyroid artery and ascending branch of inferior thyroid artery.
- Internal carotid artery comprises 4 parts: Cervical, petrous, cavernous and cerebral.
- Scalenus anterior can press upon the subclavian artery and brachial plexus, causing nervous and vascular changes in upper limb.
- Phrenic nerve (C4) supplies motor fibres to musculature of diaphragm. It carries sensory fibres from peritoneum underlying diaphragm, mediastinal pleura and pericardium.
- Styloid apparatus comprises styloglossus (XII), stylohyoid (VII), stylopharyngeus muscles (IX); and stylohyoid and stylomandibular ligaments.

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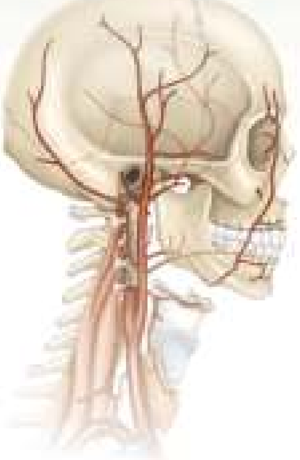
1. Follicular cells and activity of thyroid gland
2. Thyroglossal cyst and fistula
3. Blood–thymic barrier
4. Further reading
5. Viva voce questions



Chapter

9

Prevertebral and Paravertebral Regions

The prevertebral region of the neck extends from the base of skull, from the C1 to T2 vertebrae. The paravertebral region of the neck lies on either side of the prevertebral region and extends from the transverse process of C1 vertebra to the first rib (Fig. 9.1).

Prevertebral region: It contains:

1. Prevertebral (anterior vertebral) muscles: Rectus capitis anterior, rectus capitis lateralis, longus colli (cervicis) and longus capitis
2. 1st and 2nd parts of vertebral arteries
3. Joints of the neck.

Paravertebral region: It contains:

1. Three scalene muscles
2. Cervical plexus and its branches
3. Phrenic nerve
4. Cervical pleura.

PREVERTEBRAL MUSCLES
(ANTERIOR VERTEBRAL MUSCLES)

There are four prevertebral or anterior vertebral muscles (Figs 9.2 to 9.4, Plate 9.1):

1. Rectus capitis anterior
2. Rectus capitis lateralis
3. Longus colli (cervicis)
4. Longus capitis.

Features

- All these are covered by thick prevertebral fascia.
- They are weak flexors of the head and neck.
- They are supplied by ventral primary rami of cervical spinal nerves.

The origin, insertion, nerve supply and actions of these muscles are described in Table 9.1.

DISSECTION

Remove the scalenus anterior muscle. Identify deeply placed anterior and posterior intertransverse muscles. Cut through the anterior intertransverse muscles to expose the second part of vertebral artery. First part was seen as the branch arising from the first part of the subclavian artery. Its third part was seen in the suboccipital triangle. The fourth part lies in the cranial cavity.

VERTEBRAL ARTERY

The vertebral artery arises from the posterosuperior aspect of the 1st part of the subclavian artery near its commencement (Fig. 9.5, Flowchart 9.1).

Course

It passes upward to enter the foramina transversarium of the 6th cervical vertebra and traverses upward in foramina transversarium of upper 6 cervical vertebrae.

After emerging from the foramina transversarium of the 1st cervical vertebrae, this artery winds backward around the lateral mass of atlas. Further, the artery enters the cranial cavity through the foramen magnum.

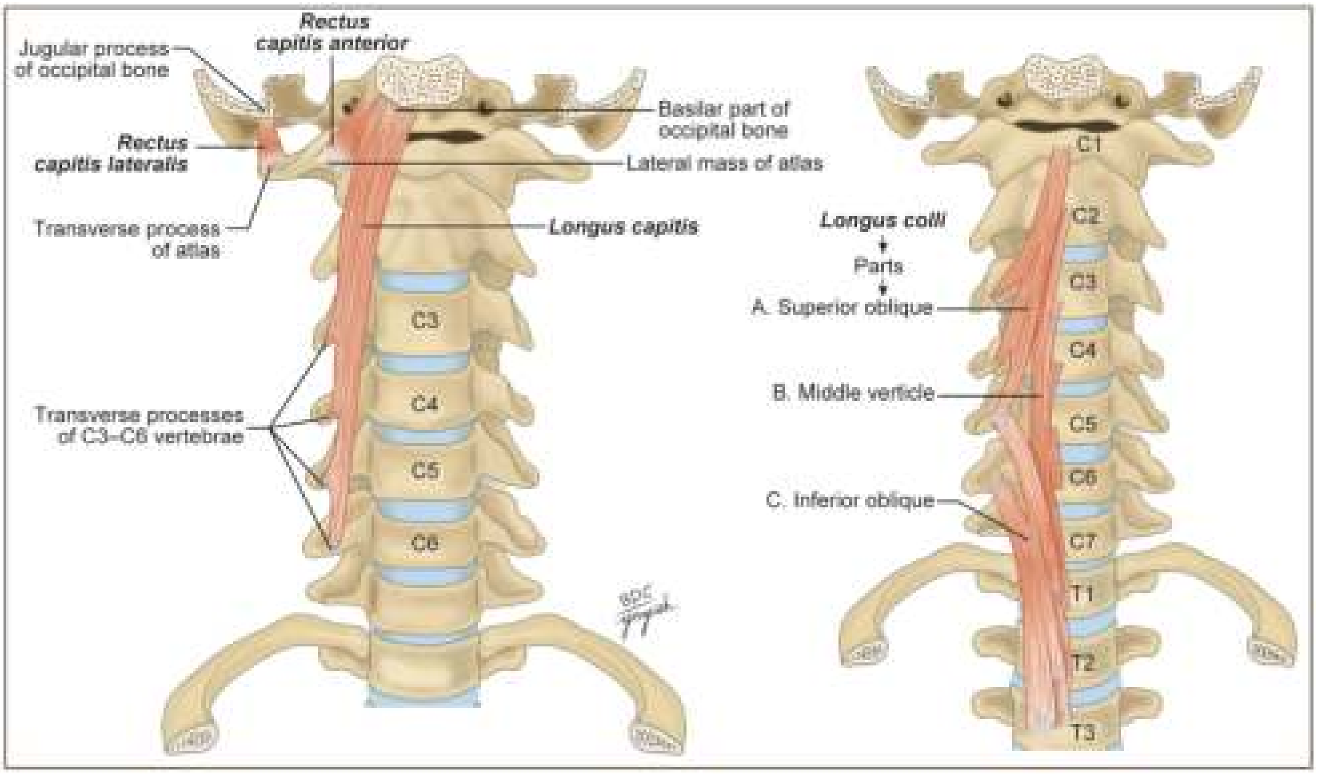
In the cranial cavity, at the lower border of pons, it joins with the similar artery of the opposite side to form *basilar artery*.

Parts of Vertebral Artery

Based on the location, the vertebral artery is divided into four parts as follows:

1. *First (cervical part)* extends from the 1st part of subclavian artery to the foramen transversarium of C6 vertebra. The 1st part of vertebral artery is present in the *scalenovertebral triangle*.
2. *Second (vertebral part)* lies within the foramen transversaria of C6 to C1 vertebrae.
3. *Third (suboccipital part)* extends from foramen transversarium of C1 vertebra to the foramen magnum of skull. The loop of third part of vertebral artery dampens down the arterial pulsation within the cranial cavity. It lies within the suboccipital triangle.
4. *Fourth (intracranial part)* extends from foramen magnum to the lower border of the pons.

Plate 9.1: Prevertebral muscles


Jugular process of occipital bone
Rectus capitis anterior
Basilar part of occipital bone
Rectus capitis lateralis
Lateral mass of atlas
Transverse process of atlas
Longus capitis
C3
C4
C5
C6
Transverse processes of C3–C6 vertebrae
Longus colli
Parts
A. Superior oblique
B. Middle verticle
C. Inferior oblique
C1
C2
C3
C4
C5
C6
C7
T1
T2
T3

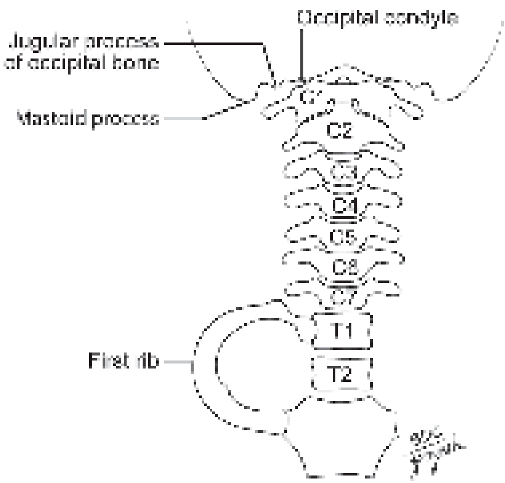

Occipital condyle
Jugular process of occipital bone
Mastoid process
C1
C2
C3
C4
C5
C6
C7
T1
T2
First rib

Fig. 9.1: Bony framework of the pre- and paravertebral regions and the root of the neck

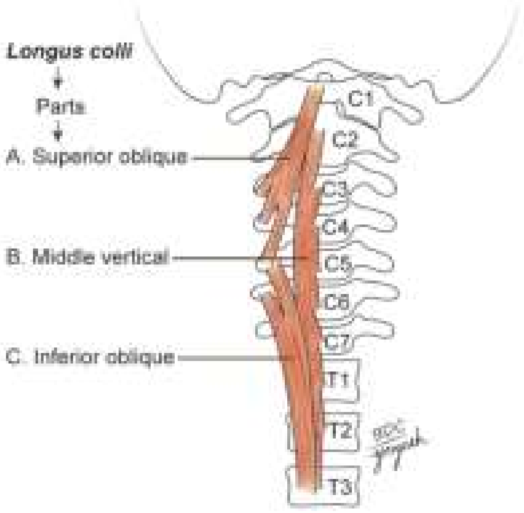

Longus colli
Parts
A. Superior oblique
B. Middle vertical
C. Inferior oblique
C1
C2
C3
C4
C5
C6
C7
T1
T2
T3

Fig. 9.3: Longus colli muscle

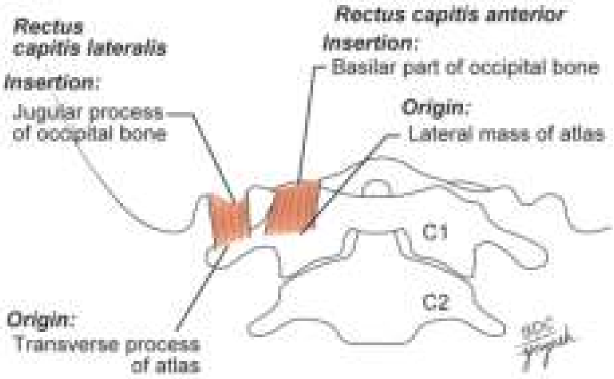

Rectus capitis lateralis
Insertion:
Jugular process of occipital bone
Rectus capitis anterior
Insertion:
Basilar part of occipital bone
Origin:
Lateral mass of atlas
C1
C2
Origin:
Transverse process of atlas

Fig. 9.2: Rectus capitis anterior and rectus capitis lateralis muscles

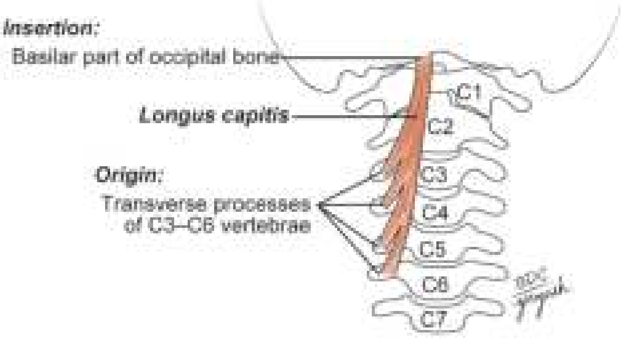

Insertion:
Basilar part of occipital bone
Longus capitis
Origin:
Transverse processes of C3–C6 vertebrae
C1
C2
C3
C4
C5
C6
C7

Fig. 9.4: Longus capitis muscle

TABLE 9.1: The origin, insertion, nerve supply and actions of prevertebral muscles

Muscle	*Origin*	*Insertion*	*Nerve supply*	*Actions*
Rectus capitis anterior This is a very short and flat muscle. It lies deep to the longus capitis	Anterior surface of lateral mass of ***atlas***	Basilar part of the occipital bone	Ventral ramus of nerve C1	Flexes the head
Rectus capitis lateralis This is a short, flat muscle	Upper surface of transverse process of ***atlas***	Inferior surface of jugular process of the occipital bone	Ventral rami of nerves C1, C2	Flexes the head laterally
Longus colli (cervicis) This muscle extends from the atlas to the C3 vertebra. It has upper and lower oblique parts and a middle vertical part	a. ***Upper oblique part*** is from the anterior tubercles of the transverse processes of C3, C4, C5 vertebrae b. ***Lower oblique part*** is from bodies of upper 2–3 thoracic vertebrae c. ***Middle vertical part*** is from bodies of upper 3 thoracic and lower 3 cervical vertebrae	a. ***Upper oblique part*** is into the anterior tubercle of the atlas b. ***Lower oblique part*** is into the anterior tubercles of the transverse processes of 5th and 6th cervical vertebrae c. ***Middle vertical part*** is into bodies of 2, 3, 4 vertebrae cervical vertebrae	Ventral rami of nerves C3–C8	a. Flexes the neck b. Oblique parts flex the neck laterally c. Lower oblique part rotates the neck to the opposite side
Longus capitis It overlaps the longus colli. It is thick above and narrow below	Anterior tubercles of transverse processes of cervical 3–6 vertebrae	Inferior surface of basilar part of occipital bone	Ventral rami of nerves C1–C3	Flexes the head

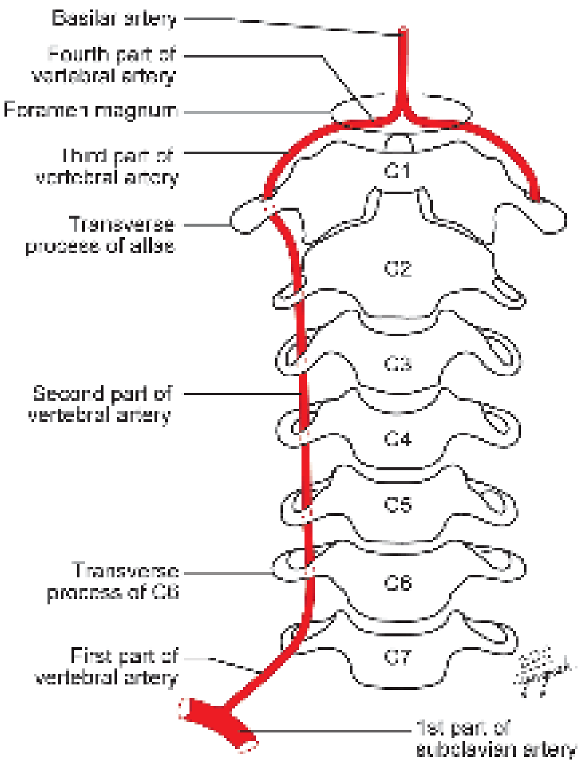
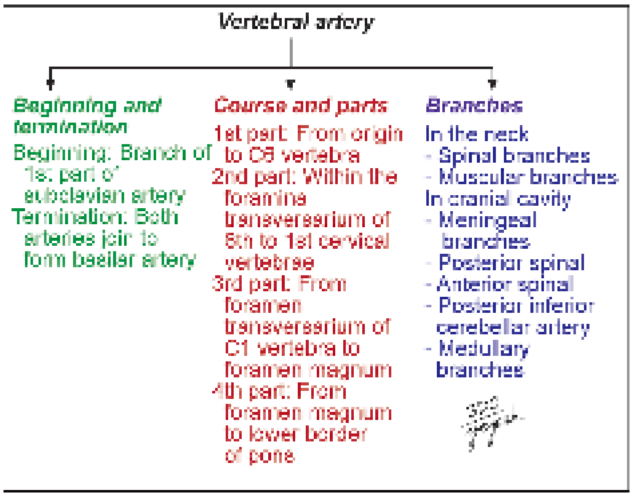

Basilar artery
Fourth part of vertebral artery
Foramen magnum
Third part of vertebral artery
Transverse process of atlas
Second part of vertebral artery
Transverse process of C6
First part of vertebral artery
1st part of subclavian artery
C1
C2
C3
C4
C5
C6
C7

Fig. 9.5: Scheme showing parts of the vertebral artery, as seen from the front

Branches of Vertebral Artery

First part has no branches.

Flowchart 9.1: Vertebral artery


Vertebral artery
Beginning and termination
Beginning: Branch of 1st part of subclavian artery
Termination: Both arteries join to form basilar artery
Course and parts
1st part: From origin to C6 vertebra
2nd part: Within the foramina transversarium of 6th to 1st cervical vertebrae
3rd part: From foramen transversarium of C1 vertebra to foramen magnum
4th part: From foramen magnum to lower border of pons
Branches
In the neck
- Spinal branches
- Muscular branches
In cranial cavity
- Meningeal branches
- Posterior spinal
- Anterior spinal
- Posterior inferior cerebellar artery
- Medullary branches

In the neck:

1. Spinal branches from the 2nd part of the artery
2. Muscular branches from the 3rd part of the artery.

***In the cranial cavity*:** They arise from the 4th (cranial) part of the vertebral artery.

1. Meningeal branches
2. Posterior spinal artery
3. Anterior spinal artery
4. Posterior inferior cerebellar artery
5. Medullary branches.

Development of Vertebral Artery (Fig. 9.6)

1. *First part*: Extends from subclavian artery to foramen transversarium of sixth cervical vertebra – develops from dorsal division of seventh cervical intersegmental artery.
2. *Second part*: Extends through foramina transversarium from sixth to first cervical vertebrae – develops from postcostal anastomosis.
3. *Third part*: Extends from foramina transversarium and rests on posterior arch of the atlas – develops from spinal branch of first cervical intersegmental artery.
4. *Fourth part*: Intracranial part – develops from preneural division of spinal branch of basilar artery.

TRACHEA

The trachea (Latin rough air vessel) is a non-collapsible, wide tube, forming the beginning of the lower respiratory passages. It is kept patent because of the presence of C-shaped cartilaginous 'rings' in its wall. The cartilages are deficient posteriorly, this part of the wall being made up of muscle (trachealis) and fibrous tissue. The soft posterior wall allows expansion of the oesophagus during passage of food.

Dimensions

The *trachea* is about 10 to 15 cm long. Its upper half lies in the neck and its lower half in the superior mediastinum. The external diameter measures 2 cm in the male and 1.5 cm in the female. The lumen is smaller in the living than in cadavers. It is about 3 mm at 1 year of age, and corresponds to the age in years during childhood, with a maximum of 12 mm at puberty.

Trachea divides into right and left principal bronchi at the level of lower border of T6 vertebra (42nd*Grey's Anatomy*) (Previous concept: Trachea bifurcates at the lower border of T4 vertebra.)

Cervical Part of Trachea

1. The trachea begins at the lower border of the cricoid cartilage opposite the lower border of vertebra C6. It runs downwards and slightly backward in front of the oesophagus, follows the curvature of the spine, and enters the thorax in the median plane
2. In the neck, the trachea is comparatively superficial and has the following relations.

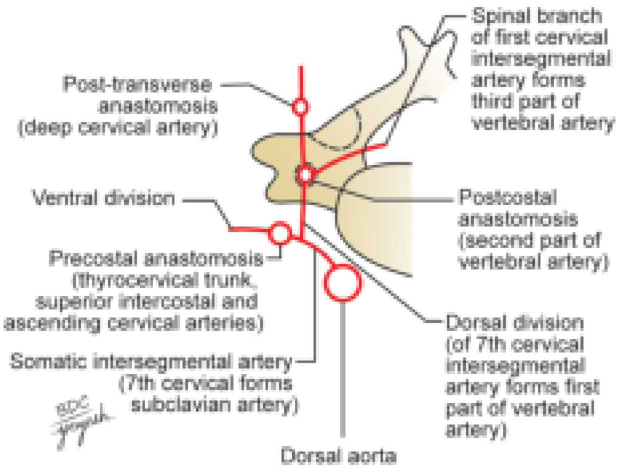

Spinal branch of first cervical intersegmental artery forms third part of vertebral artery
Post-transverse anastomosis (deep cervical artery)
Ventral division
Postcostal anastomosis (second part of vertebral artery)
Precostal anastomosis (thyrocervical trunk, superior intercostal and ascending cervical arteries)
Dorsal division (of 7th cervical intersegmental artery forms first part of vertebral artery)
Somatic intersegmental artery (7th cervical forms subclavian artery)
Dorsal aorta

Fig. 9.6: Development of vertebral artery

Anterior

1. Isthmus of the thyroid gland covering the second and third tracheal rings (*see* Fig. 8.2)
2. Inferior thyroid veins below the isthmus (*see* Fig. 8.9)
3. Pretracheal fascia enclosing the thyroid and the inferior thyroid veins
4. Sternohyoid and sternothyroid muscles (*see* Fig. 8.5)
5. Investing layer of the deep cervical fascia and the suprasternal space
6. The skin and superficial fascia
7. In children, the left brachiocephalic vein extends into the neck and then lies in front of the trachea.

Posterior

1. Oesophagus
2. Longus colli
3. Recurrent laryngeal nerve in the tracheo-oesophageal groove.

On Each Side

1. The corresponding lobe of the thyroid gland.
2. The common carotid artery within the carotid sheath.

Vessels and Nerves

Arterial supply: Inferior thyroid arteries.

Venous drainage: Left brachiocephalic vein.

Lymphatic drainage: Peritracheal and paratracheal lymph nodes.

Nerve supply: Trachea is supplied by autonomic nerves as follows:

A. *Parasympathetic nerves*: They come from vagus and recurrent laryngeal nerves. These are sensory and secretomotor to mucous membrane and motor to trachealis muscle
B. *Sympathetic nerves*: They come from middle cervical ganglion along the inferior thyroid artery. These are vasomotor.

CLINICAL ANATOMY

- The trachea may be compressed by pathological enlargements of the thyroid, the thymus, lymph nodes and the aortic arch. This causes dyspnoea, irritative cough and often a husky voice.
- ***Tracheostomy*** is an emergency operation done in cases of laryngeal obstruction (foreign body, diphtheria, carcinoma, etc.). It is commonly done in the retrothyroid region after retracting the isthmus of the thyroid gland.

OESOPHAGUS

The oesophagus is a muscular food passage lying between the trachea and the vertebral column.

The oesophagus is a downward continuation of the pharynx and begins at the lower border of the cricoid cartilage, opposite the lower border of the body of vertebra C6. It passes downwards behind the trachea, traverses the superior and posterior mediastina of the thorax and ends by opening into the cardiac end of the stomach in the abdomen. It is about 25 cm long.

It has three parts:

1. Cervical
2. Thoracic
3. Abdominal.

Cervical Part

The cervical part of the oesophagus is related:

1. *Anteriorly*, to the trachea and to the right and left recurrent laryngeal nerves.
2. *Posteriorly*, to the longus colli muscle and the vertebral column.
3. *On each side*, to the corresponding (*see* Fig. 8.5) lobe of the thyroid gland; and on the left side, to the thoracic duct.

The cervical part of the oesophagus is supplied by the inferior thyroid arteries. Its veins drain into the left brachiocephalic vein. Its lymphatics pass to the deep cervical lymph nodes. The oesophagus is narrowest at its junction with the pharynx, the junction being the narrowest part of the gastrointestinal tract, except for the vermiform appendix.

For thoracic part of oesophagus study, *see* Chapter 20, *BD Chaurasia's Human Anatomy*, *Volume 1*.

CLINICAL ANATOMY

Oesophagus has four natural constrictions (Fig. 9.7).

1. *First constriction*: At pharyngoesophageal junction, 15 cm (6 inches) from incisor teeth. It is produced by cricopharyngeus part of inferior constrictor muscle of pharynx.
2. *Second constriction*: At the crossing of arch of the aorta, 23 cm (9 inches) from incisor teeth.
3. *Third constriction*: At the crossing of the left principal bronchus, 28 cm (11 inches) from incisor teeth.
4. *Fourth constriction*: At the passage through the diaphragm, 40 cm (15 inches) from incisor teeth.

PARAVERTEBRAL REGION

SCALENE MUSCLES

There are usually three scalene muscles (Plate 9.2):

1. Scalenus anterior
2. Scalenus medius
3. Scalenus posterior.

Features

1. The scalenus medius is the largest and the scalenus posterior is the smallest of three
2. These muscles extend from the transverse processes of cervical vertebrae to the first two ribs

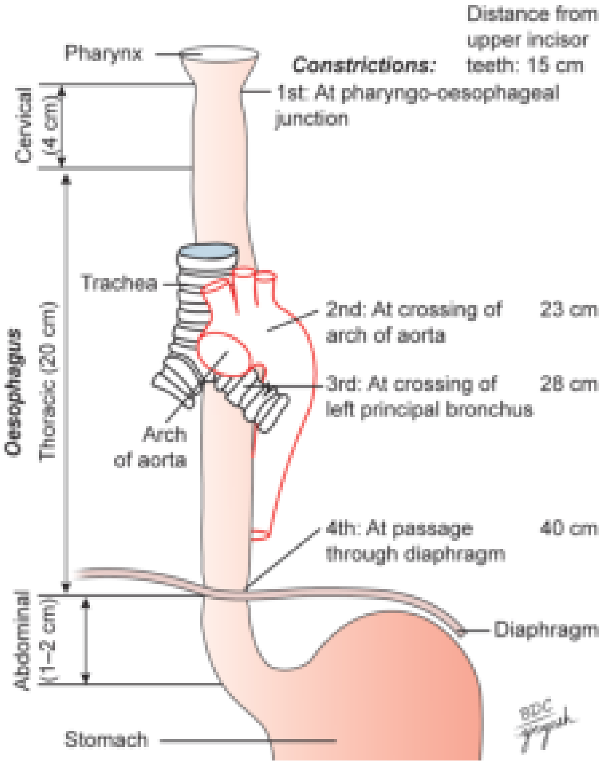

Distance from upper incisor teeth: 15 cm
Pharynx
Constrictions:
1st: At pharyngo-oesophageal junction
Cervical (4 cm)
Trachea
2nd: At crossing of arch of aorta
23 cm
3rd: At crossing of left principal bronchus
28 cm
Arch of aorta
Oesophagus
Thoracic (20 cm)
4th: At passage through diaphragm
40 cm
Diaphragm
Abdominal (1–2 cm)
Stomach

Fig. 9.7: Natural constrictions of the oesophagus

3. They can, therefore, either elevate these ribs or bend the cervical part of the vertebral column laterally.

Note: Sometimes a fourth, rudimentary scalene muscle, the ***scalenus minimus*** is present. It arises from the anterior border of the transverse process of vertebra C7 and is inserted into the inner border of the 1st rib behind the groove for the subclavian artery and into the dome of the cervical pleura. The *suprapleural membrane* is regarded as the expansion of this muscle. Contraction of the scalenus minimus pulls the dome of the cervical pleura.

The origin, insertion, nerve supply and actions of these muscles are described in Table 9.2.

Relations of Scalene Anterior Muscles (Fig. 9.8)

The scalenus anterior is a *key* muscle of the lower part of the neck because of its intimate relations to many important structures in this region. It is a useful surgical landmark.

Anterior relations

1. Prevertebral fascia
2. Phrenic nerve
3. Two arteries – transverse cervical and suprascapular arteries
4. Two veins – anterior jugular and subclavian veins
5. Two muscles – inferior belly of omohyoid and clavicular head of sternocleidomastoid
6. Clavicle.

Posterior relations

1. Root of brachial plexus
2. Subclavian artery
3. Scalenus medius and posterior muscles
4. Cervical pleura
5. Suprapleural membrane.

Plate 9.2: Scalene muscles

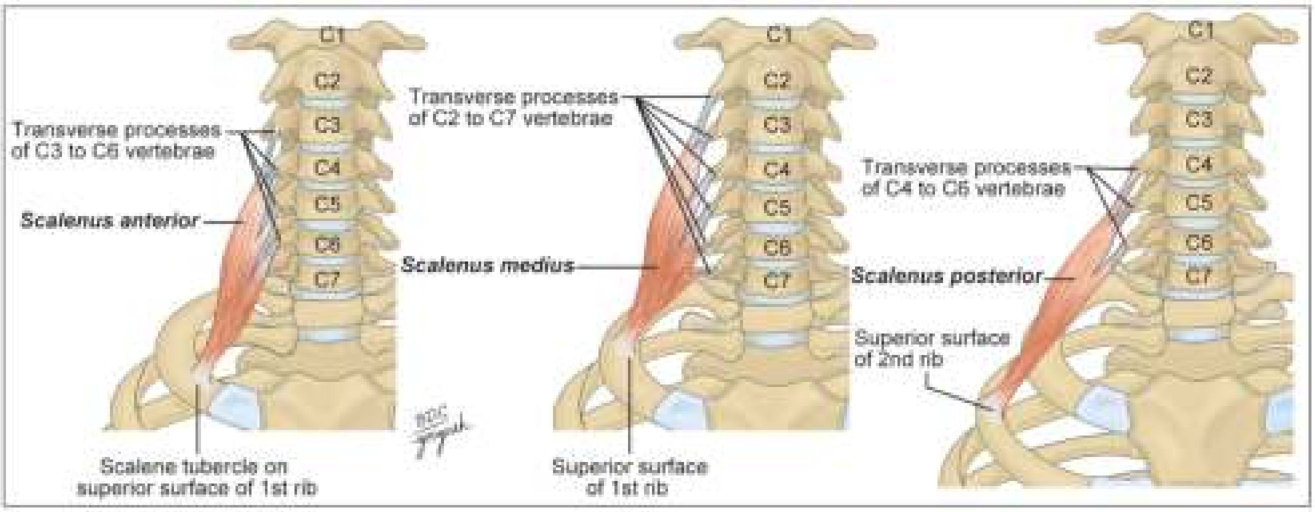

C1
C2
C3
C4
C5
C6
C7
Transverse processes of C3 to C6 vertebrae
Scalenus anterior
Scalene tubercle on superior surface of 1st rib
Transverse processes of C2 to C7 vertebrae
Scalenus medius
Superior surface of 1st rib
Transverse processes of C4 to C6 vertebrae
Scalenus posterior
Superior surface of 2nd rib

TABLE 9.2: The origin, insertion, nerve supply and actions of scalene muscles

Muscle	*Origin*	*Insertion*	*Nerve supply*	*Actions*
1. **Scalenus anterior**	Anterior tubercles of transverse processes of **C3 to C6** vertebrae	Scalene tubercle and adjoining ridge on the superior surface of the **1st *rib*** (between subclavian artery and vein)	Ventral rami of nerves C4–C6	a. Anterolateral flexion of cervical spine b. Rotates cervical spine to opposite side c. Elevates the 1st rib during inspiration d. Stabilises the neck along with other muscles
2. **Scalenus medius**	a. Posterior tubercles of transverse processes of **C2 to C7** vertebrae b. Transverse process of axis and sometimes also of the atlas vertebra	Superior surface of the ***1st rib*** behind the groove for the subclavian artery	Ventral rami of nerves C3–C8	a. Lateral flexion of the cervical spine b. Elevation of 1st rib c. Stabilises neck along with other muscles
3. **Scalenus posterior**	Posterior tubercles of transverse processes of **C4 to C6** vertebrae	Outer surface of the ***2nd rib*** behind the tubercle for the serratus anterior	Ventral rami of nerves C6–C8	a. Lateral flexion of cervical spine b. Elevation of the 2nd rib c. Stabilises neck along with other muscles

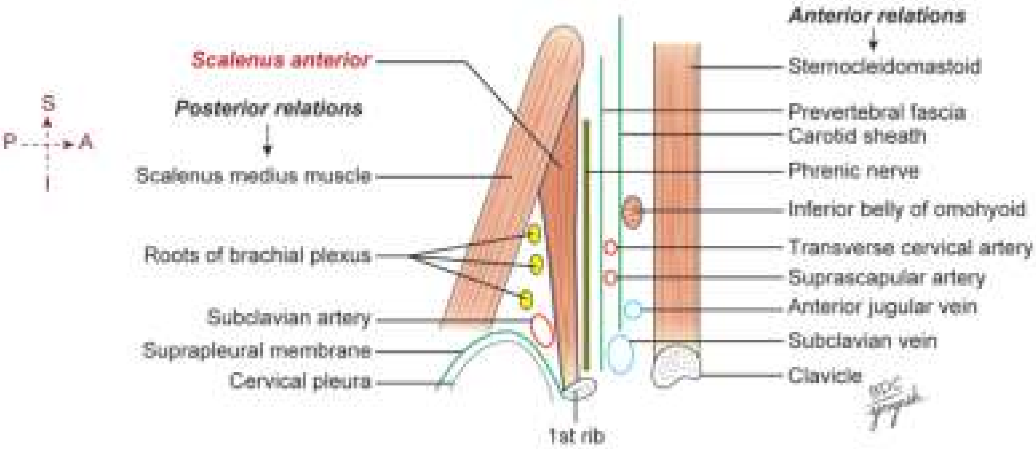

S
P
A
I
Scalenus anterior
Posterior relations
Scalenus medius muscle
Roots of brachial plexus
Subclavian artery
Suprapleural membrane
Cervical pleura
1st rib
Anterior relations
Sternocleidomastoid
Prevertebral fascia
Carotid sheath
Phrenic nerve
Inferior belly of omohyoid
Transverse cervical artery
Suprascapular artery
Anterior jugular vein
Subclavian vein
Clavicle

Fig. 9.8: Lateral view of the scalene muscles with a few related structures

Relation of medial border

1. Forms the lateral boundary of scalenovertebral triangle
2. Vertebral artery and contents of scalenovertebral triangle.

Relations of lateral border: Trunks of brachial plexus emerge deep to the lateral border.

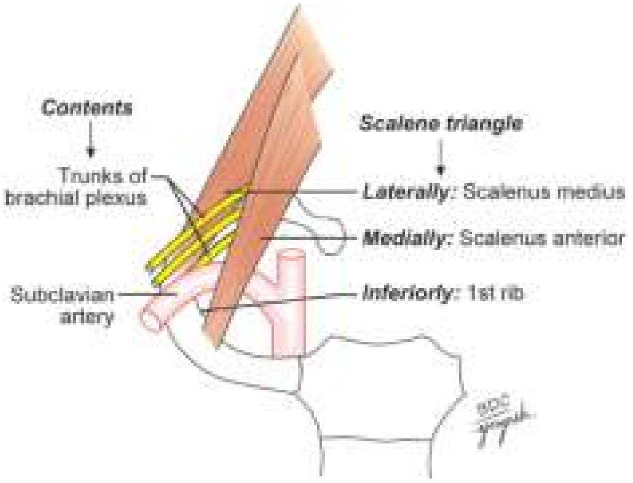
SCALENE TRIANGLE

It is also called *subclavian triangle*. It is a narrow triangular gap bounded as follows (Fig. 9.9):

Inferiorly (base): 1st rib
Medially: Scalenus anterior
Laterally: Scalenus medius
Contact: It gives passage to:

1. Subclavian artery
2. Trunks of brachial plexus

Note: ***Scalene syndrome*** occurs due to compression of the lower trunk of brachial plexus and the subclavian artery in the scalene triangle. It may occur due to the cervical rib or spasm of scalene muscle. Due to compression of subclavian artery, there will be ischaemic pain and absence of radial pulse. The compression of lower trunk (C8, T1) produces tingling sensation and numbness or sensory loss along the medial border of forearm and hand, and the paralysis and muscle wasting of intrinsic muscles of hand.



Contents
Trunks of brachial plexus
Subclavian artery
Scalene triangle
Laterally: Scalenus medius
Medially: Scalenus anterior
Inferiorly: 1st rib

Fig. 9.9: Scalene triangle

SCALENOVERTEBRAL TRIANGLE

It is also called *triangle of the vertebral artery*. It is a bilaterally placed triangular space at the root of the neck (Fig. 9.10, Flowchart 9.2).

Boundaries

Medial: Lower oblique part of longus colli
Lateral: Scalenus anterior
Apex: Transverse process of C6 vertebra
Base: 1st part of subclavian artery
Floor (posterior wall):

1. Transverse process of C7 vertebra
2. Ventral ramus of C8 spinal nerve
3. Neck of 1st rib
4. Cupola of cervical pleura

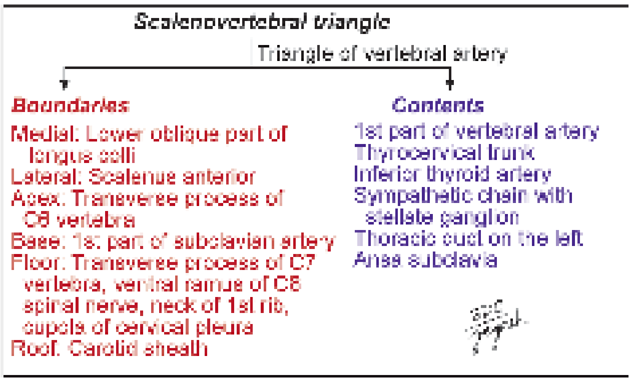
Roof: Carotid sheath.

Contents

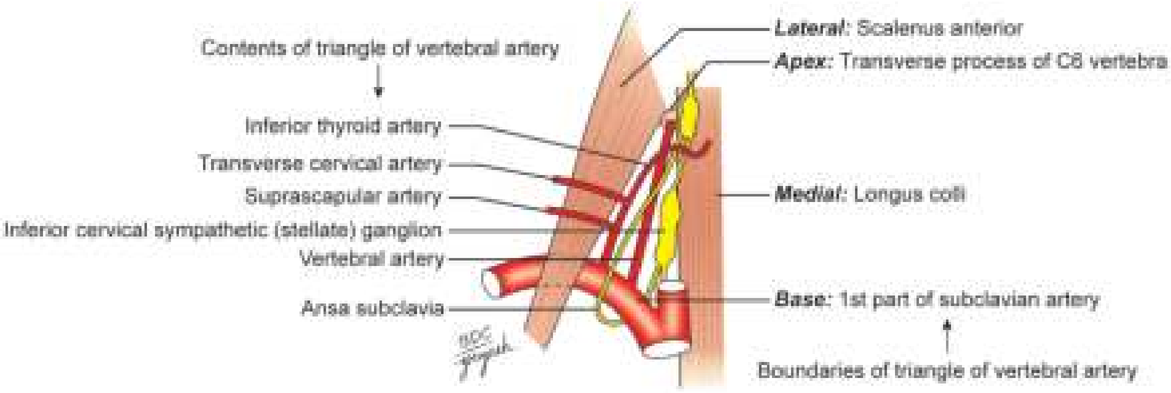
1. 1st part of vertebral artery and accompanying vein
2. Thyrocervical trunk
3. Inferior thyroid artery
4. Sympathetic chain with stellate ganglion
5. Thoracic duct on the left
6. Ansa subclavia

Note: *Ansa subclavia* is an anterior root of nerve fibres connecting the middle and inferior cervical sympathetic ganglia. It loops around the 1st part of subclavian artery.

Flowchart 9.2: Scalenovertebral triangle



Scalenovertebral triangle
Triangle of vertebral artery
Boundaries
Medial: Lower oblique part of longus colli
Lateral: Scalenus anterior
Apex: Transverse process of C6 vertebra
Base: 1st part of subclavian artery
Floor: Transverse process of C7 vertebra, ventral ramus of C8 spinal nerve, neck of 1st rib, cupola of cervical pleura
Roof: Carotid sheath
Contents
1st part of vertebral artery
Thyrocervical trunk
Inferior thyroid artery
Sympathetic chain with stellate ganglion
Thoracic duct on the left
Ansa subclavia



Contents of triangle of vertebral artery
Inferior thyroid artery
Transverse cervical artery
Suprascapular artery
Inferior cervical sympathetic (stellate) ganglion
Vertebral artery
Ansa subclavia
Lateral: Scalenus anterior
Apex: Transverse process of C6 vertebra
Medial: Longus colli
Base: 1st part of subclavian artery
Boundaries of triangle of vertebral artery

Fig. 9.10: Triangle of vertebral artery (right anterior view, Note: Thoracic duct is a content of the left triangle of vertebral artery)

DISSECTION

Clean and define the cervical parts of the trachea and oesophagus.

Scalenus anterior has been seen in relation to subclavian artery. Scalenus medius is one of the muscles forming floor of posterior triangle of neck.

Scalenus posterior lies deep to the medius.

CERVICAL PLEXUS

Formation

The cervical plexus is formed by the ventral rami of C1 to C4 spinal nerves (Fig. 9.11). The rami emerge between the anterior and posterior tubercles of the cervical transverse processes, grooving the costotransverse bars. The four roots are connected with one another to form three loops.

Position and Relations of the Plexus

The plexus is related:

1. *Posteriorly*, to the muscles which arise from the posterior tubercles of the transverse processes, i.e. the levator scapulae and the scalenus medius
2. *Anteriorly*, to the prevertebral fascia, the internal jugular vein and the sternocleidomastoid.

Branches

Superficial (Cutaneous) Branches

1. Lesser occipital (C2)
2. Great auricular (C2, C3)
3. Transverse (anterior) cutaneous nerve of the neck (C2, C3)
4. Supraclavicular (C3, C4).

These are described in Chapter 3.

Deep Branches

Communicating Branches

1. Grey rami pass from the superior cervical ganglion to the roots of C1–C4 nerves
2. A branch from C1 joins the hypoglossal nerve and carries fibres for supply of the thyrohyoid and geniohyoid muscles (directly) and the superior belly of the omohyoid through the descendens hypoglossi
3. A branch each from C2, C3 to the sternocleidomastoid and branches from C3 and C4 to the trapezius communicate with the accessory nerve.

Muscular Branches

Muscles supplied solely by cervical plexus:

1. Rectus capitis anterior from C1
2. Rectus capitis lateralis from C1, C2
3. Longus capitis from C1 to C3
4. Lower root of ansa cervicalis (descendens cervicalis) from C2, C3 (to sternohyoid, sternothyroid and inferior belly of omohyoid).

Muscles supplied by cervical plexus along with the brachial plexus or the spinal accessory nerve are:

1. Sternocleidomastoid from C2 to C3 along with accessory nerve
2. Trapezius from C3 to C4 along with accessory nerve
3. Levator scapulae from C3 to C5 (dorsal scapular nerve)
4. The diaphragm from phrenic nerve from C3 to C5
5. Longus colli from C3 to C8
6. Scalenus medius from C3 to C8
7. Scalenus anterior from C4 to C6
8. Scalenus posterior from C6 to C8.

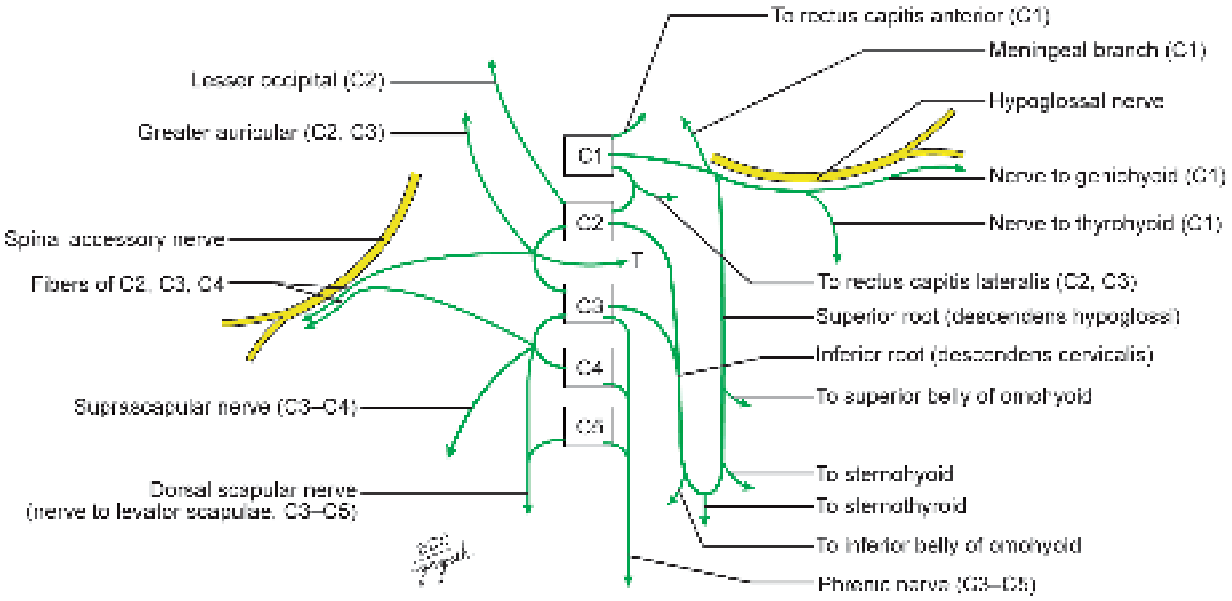

To rectus capitis anterior (C1)
Meningeal branch (C1)
Lesser occipital (C2)
Hypoglossal nerve
Greater auricular (C2, C3)
C1
Nerve to geniohyoid (C1)
C2
Nerve to thyrohyoid (C1)
Spinal accessory nerve
T
Fibers of C2, C3, C4
To rectus capitis lateralis (C2, C3)
C3
Superior root (descendens hypoglossi)
C4
Inferior root (descendens cervicalis)
To superior belly of omohyoid
Suprascapular nerve (C3–C4)
C5
To sternohyoid
Dorsal scapular nerve
(nerve to levator scapulae, C3–C5)
To sternothyroid
To inferior belly of omohyoid
Phrenic nerve (C3–C5)

Fig. 9.11: Cervical plexus and its branches (T: transverse cutaneous nerve of neck [C2, C3], *Note*: Grey rami communicantes and branches for longus capitis, longus coli, scalene muscles are not shown to maintain the clarity)

PHRENIC NERVE

This is a ***mixed*** nerve carrying motor fibres to the diaphragm and sensory fibres from the diaphragm, pleura, pericardium and part of the peritoneum (Fig. 9.12, Flowchart 9.3).

Origin

Phrenic nerve arises chiefly from the fourth cervical nerve but receives contributions from third and fifth cervical nerves. The contribution from C5 may come directly from the root or indirectly through the nerve to the subclavius. In the latter case, the contribution is known as the *accessory phrenic nerve*.

Course and Relations in the Neck

1. The nerve is formed at the lateral border of the scalenus anterior, opposite the middle of the sternocleidomastoid, at the level of the upper border of the thyroid cartilage.
2. It runs vertically downwards on the anterior surface of the scalenus anterior. Since the muscle is oblique, the nerve appears to cross it obliquely from lateral to medial border. In this part of its course, the nerve is related anteriorly to the prevertebral fascia, the inferior belly of the omohyoid, the transverse cervical artery, the suprascapular artery, the internal jugular vein, the sternocleidomastoid and the thoracic duct on left side (Fig. 9.12).
3. After leaving the anterior surface of scalenus anterior, the nerve runs downwards on the cervical pleura behind the commencement of the brachiocephalic vein. Here, it crosses the internal thoracic artery (either anteriorly or posteriorly) from lateral to medial side, and enters the thorax behind the first costal cartilage. On the left side, the nerve leaves (crosses) the medial margin of the scalenus anterior at a higher level and crosses in front of the first part of the subclavian artery.

Branches

1. It supplies diaphragm from its under surface through four sets of branches on each side — anteromedial, anterolateral, posteromedial and posterolateral.
2. *Right phrenic nerve* — right half of the diaphragm, part of right crus.
3. *Left phrenic nerve* — left half of the diaphragm, left crus and part of right crus
4. Also supplies pleura and peritoneum.

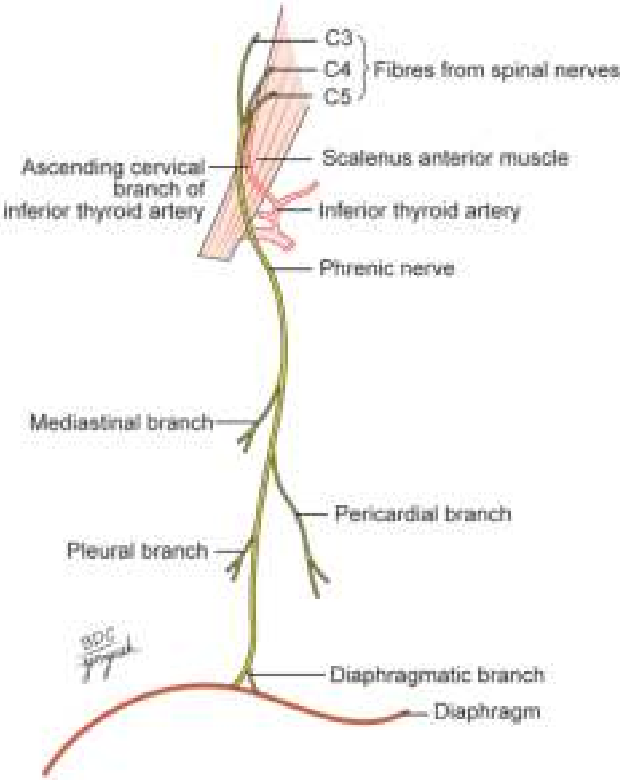
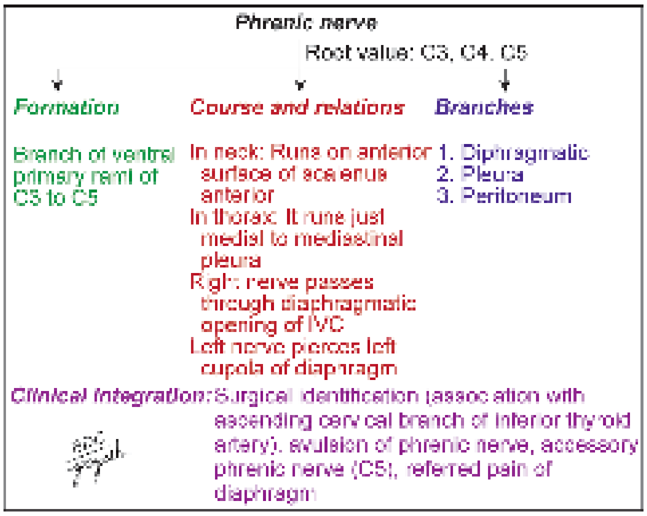

C3
C4
C5
Fibres from spinal nerves
Scalenus anterior muscle
Ascending cervical branch of inferior thyroid artery
Inferior thyroid artery
Phrenic nerve
Mediastinal branch
Pericardial branch
Pleural branch
Diaphragmatic branch
Diaphragm

Fig. 9.12: Formation, course and distribution of phrenic nerve

Flowchart 9.3: Phrenic nerve


Phrenic nerve
Root value: C3, C4, C5
Formation
Course and relations
Branches
Branch of ventral primary rami of C3 to C5
In neck: Runs on anterior surface of scalenus anterior
In thorax: It runs just medial to mediastinal pleura
Right nerve passes through diaphragmatic opening of IVC
Left nerve pierces left cupola of diaphragm
1. Diphragmatic
2. Pleura
3. Peritoneum
Clinical Integration: Surgical identification (association with ascending cervical branch of inferior thyroid artery), avulsion of phrenic nerve, accessory phrenic nerve (C5), referred pain of diaphragm

CLINICAL ANATOMY

- ***Surgical identification:*** In the neck, phrenic nerve is accompanied by ascending cervical branch of inferior thyroid artery. It may help for the identification of the phrenic nerve.
- ***Avulsion of phrenic nerve (old surgical method):*** Crushing or avulsion of phrenic nerve was done to paralyze half part of the diaphragm. It was useful in the treatment of severe lung disease.
- ***Accessory phrenic nerve (root value C5):*** It is the branch of nerve to subclavius (C5). It may descend in front of subclavian vein and then join phrenic nerve in the thorax (Fig. 9.13). Accessory phrenic nerve, if present, may damage the subclavian vein during avulsion of phrenic nerve → severe bleeding.
- ***Referred pain of diaphragm:*** Pain from the diaphragm get referred from phrenic nerve (C3–C5) to the shoulder region through supraclavicular nerves (C3–C4).

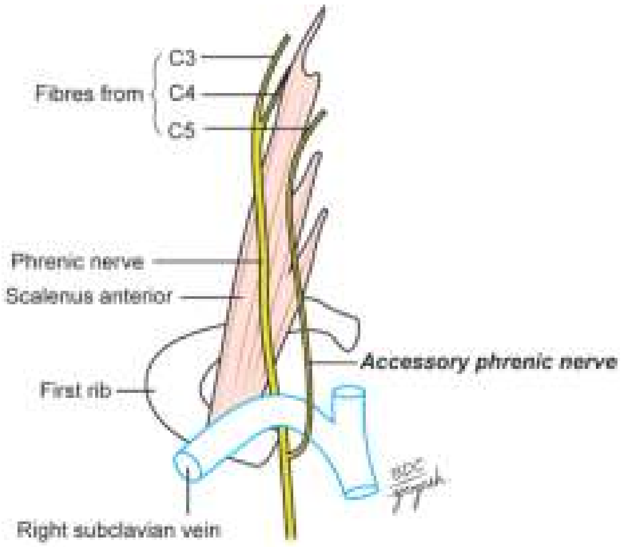

Fibres from
C3
C4
C5
Phrenic nerve
Scalenus anterior
Accessory phrenic nerve
First rib
Right subclavian vein

Fig. 9.13: Accessory phrenic nerve

JOINTS OF THE NECK

The joints of the neck include (Flowchart 9.4, Table 9.3):

1. Craniovertebral joints
   A. Atlanto-occipital joints
   B. Atlanto-axial joints
2. Joints between lower cervical vertebrae (typical cervical joints).

Typical Cervical Joints between the Lower Six Cervical Vertebrae (Figs 9.14a to e)

The bodies of cervical vertebra are united by intervertebral disc. On each side of the disc are small synovial joints called joints of Luschka or uncovertebral joints. The adjacent vertebrae are connected by several ligaments; which are as follows:

1. *Anterior longitudinal ligament* passes from the anterior surface of the body of one vertebra to another. Its upper end reaches the basilar part of the occipital bone (Fig. 9.14c).
2. *Posterior longitudinal ligament* is present on the posterior surface of the vertebral bodies within the vertebral canal. Its upper end reaches the body of the axis vertebra beyond which it continues as the *membrana tectoria*.
3. *Intertransverse ligaments* connect adjacent transverse processes.
4. *Interspinous ligaments* connect adjacent spines.
5. *Supraspinous ligaments* connect the tips of the spines of vertebrae from the seventh cervical to the sacrum. In the cervical region, they are replaced by the ligamentum nuchae.
6. ***Ligamentum nuchae*** is triangular in shape. Its apex lies at the seventh cervical spine and its base at the external occipital crest. Its anterior border is attached to cervical spines, while the posterior border is free and provides attachment to the investing layer of deep cervical fascia. The ligament gives origin to the splenius, rhomboids and trapezius muscles (Fig. 9.14e).

Flowchart 9.4: Joints of neck and their types

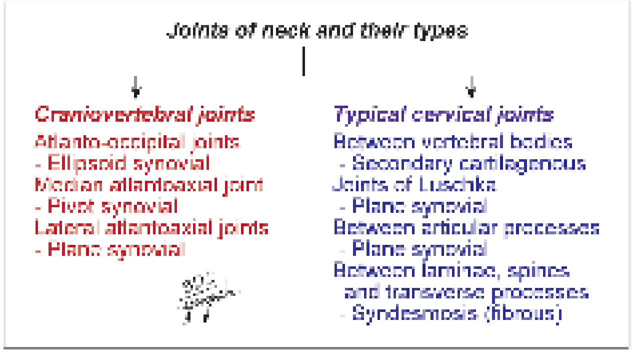

Joints of neck and their types
Craniovertebral joints
Atlanto-occipital joints
- Ellipsoid synovial
Median atlantoaxial joint
- Pivot synovial
Lateral atlantoaxial joints
- Plane synovial
Typical cervical joints
Between vertebral bodies
- Secondary cartilaginous
Joints of Luschka
- Plane synovial
Between articular processes
- Plane synovial
Between laminae, spines and transverse processes
- Syndesmosis (fibrous)

TABLE 9.3: Joints of neck and classification

Joint	*Classification*
1. Craniovertebral joints	
A. Atlanto-occipital joints	Ellipsoidal variety of synovial joint
B. Atlantoaxial joints	
i. Median atlantoaxial joints	Pivot variety of synovial joint
ii. Lateral atlantoaxial joints	Plane synovial joints
2. Typical cervical joints	
A. Joints between vertebral bodies	Secondary cartilaginous joints
B. Joints of Luschka (between the lateral margins of vertebral bodies)	Plane synovial joints
C. Joints between vertebral arches	
i. Joints between articular processes (zygapophyseal joints/facet joints)	Plane synovial joints
ii. Intervertebral syndesmosis (joints between adjacent laminae, spines and transverse processes)	Syndesmosis type of fibrous joints

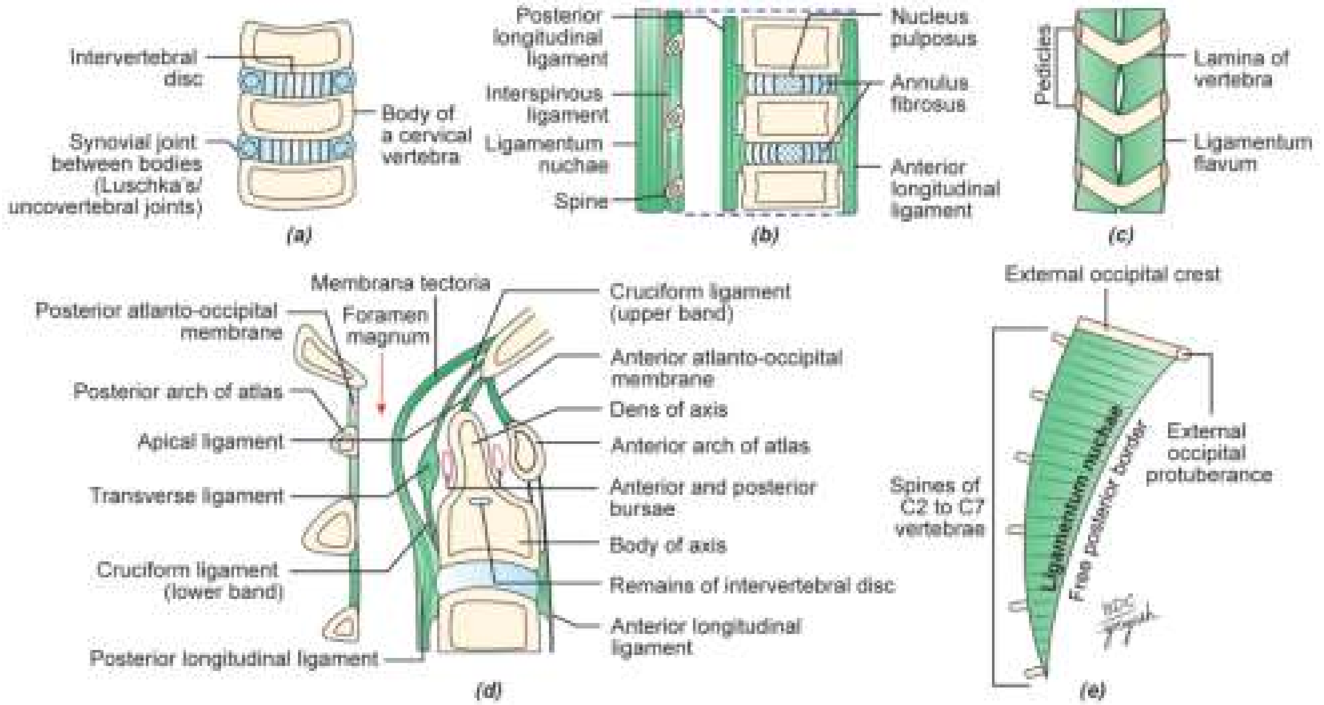
Joint between Vertebral Arches

The joint between superior and inferior articular processes of adjacent vertebrae is plane joint of synovial variety. The articular processes slope inferiorly to allow rotation of neck. These are also called zygapophyseal/facet joints.

The laminae of adjacent vertebrae are united by ligamentum flava, made up of elastic fibres. It ends at C2 level (Fig. 9.14a).

Joints between Atlas, Axis and Occipital Bone

1. The atlanto-occipital and the atlantoaxial joints are designed to permit free movements of the head on the neck (vertebral column).
2. The axis vertebra and the occipital bone are connected by very strong ligaments. Between these two bones, the atlas is held like a washer. The axis of movement


Intervertebral disc
Synovial joint between bodies (Luschka's/ uncovertebral joints)
Body of a cervical vertebra
(a)
Posterior longitudinal ligament
Interspinous ligament
Ligamentum nuchae
Spine
Nucleus pulposus
Annulus fibrosus
Anterior longitudinal ligament
(b)
Pedicles
Lamina of vertebra
Ligamentum flavum
(c)
Membrana tectoria
Posterior atlanto-occipital membrane
Foramen magnum
Posterior arch of atlas
Apical ligament
Transverse ligament
Cruciform ligament (lower band)
Posterior longitudinal ligament
Cruciform ligament (upper band)
Anterior atlanto-occipital membrane
Dens of axis
Anterior arch of atlas
Anterior and posterior bursae
Body of axis
Remains of intervertebral disc
Anterior longitudinal ligament
(d)
External occipital crest
External occipital protuberance
Spines of C2 to C7 vertebrae
Ligamentum nuchae
Free posterior border
(e)

Figs 9.14a to e: (a) Joints between vertebral bodies as seen from front, (b) side view showing the ligaments, (c) anterior view of the ligamentum flava, (d) median section through the foramen magnum and upper two cervical vertebrae showing the ligaments in this region, and (e) ligamentum nuchae

between the atlas and skull is transverse, permitting flexion and extension (nodding), whereas the axis of movement between the axis and the atlas is vertical, permitting rotation of the head.

Competency:
AN43.1 Describe and demonstrate the movements with muscles producing the movements of atlanto-occipital joint and atlantoaxial joint.

Atlanto-occipital Joints

Types and Articular Surfaces

These are synovial joints of the ellipsoid variety (Fig. 9.15).

Above: The convex occipital condyles.

Below: The superior articular facets of the atlas vertebra. These are concave. The articular surfaces are elongated and are directed forwards and medially.

Ligaments

1. ***Fibrous capsule*** *(capsular ligament)* surrounds the joint. It is thick posterolaterally and thin anteromedially.
2. ***Anterior atlanto-occipital membrane*** extends from the anterior margin of the foramen magnum above to the upper border of the anterior arch of the atlas below. Laterally, it is continuous with the anterior part of the capsular ligament, and anteriorly, it is strengthened by the cord-like anterior longitudinal ligament.
3. ***Posterior atlanto-occipital membrane*** extends from the posterior margin of the foramen magnum above, to the upper border of the posterior arch of the atlas below. Inferolaterally, it has a free margin that arches over the vertebral artery and the first cervical nerve. Laterally, it is continuous with the posterior part of the capsular ligament.

Arterial and Nerve Supply

The joint is supplied by the vertebral artery and the first cervical nerve.

Movements

Since these are ellipsoid joints, they permit movements around two axes (Figs 9.16a to c). Flexion and extension (nodding) occur around a transverse axis. Slight lateral flexion is permitted around an anteroposterior axis.

1. *Flexion* is brought about by the longus capitis and the rectus capitis anterior.
2. *Extension* is done by the rectus capitis posterior major and minor, the obliquus capitis superior, the semispinalis capitis, the splenius capitis and the upper part of the trapezius.
3. *Lateral bending* is produced by the rectus capitis lateralis, the semispinalis capitis, the splenius capitis, the sternocleidomastoid and the trapezius.

Atlantoaxial Joints

Types and Articular Surfaces

These joints comprise (Fig. 9.15, Flowchart 9.5):

1. A pair of lateral atlantoaxial joints between the inferior facets of the atlas and the superior facets of the axis. These are plane joints.
2. A median atlantoaxial joint between the dens (odontoid process) and the anterior arch and between

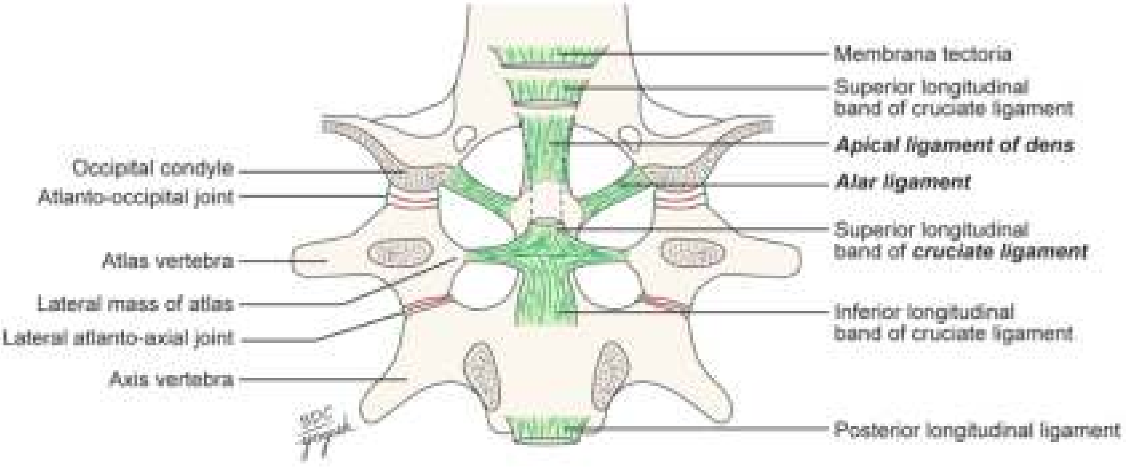
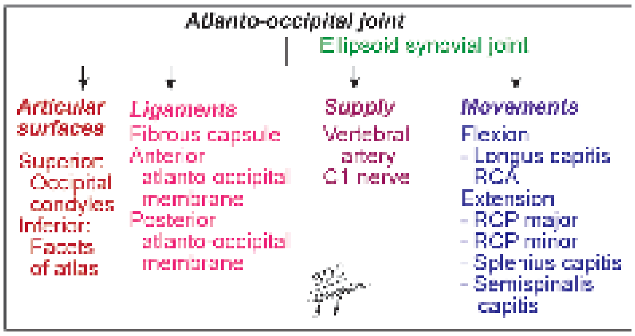

Membrana tectoria
Superior longitudinal band of cruciate ligament
Apical ligament of dens
Alar ligament
Superior longitudinal band of cruciate ligament
Inferior longitudinal band of cruciate ligament
Posterior longitudinal ligament
Occipital condyle
Atlanto-occipital joint
Atlas vertebra
Lateral mass of atlas
Lateral atlanto-axial joint
Axis vertebra

Fig. 9.15: Ligaments connecting the axis with occipital bone (coronal section passing through occipital condyles, posterior view)

Flowchart 9.5: Atlanto-occipital joint


Atlanto-occipital joint
Ellipsoid synovial joint
Articular surfaces
Superior: Occipital condyles
Inferior: Facets of atlas
Ligaments
Fibrous capsule
Anterior atlanto-occipital membrane
Posterior atlanto-occipital membrane
Supply
Vertebral artery
C1 nerve
Movements
Flexion
- Longus capitis
RCA
Extension
- RCP major
- RCP minor
- Splenius capitis
- Semispinalis capitis

(RCA: Rectus capitis anterior, RCP major: Rectus capitis posterior major, RCP minor: Rectus capitis posterior minor)

dens and transverse ligament of the atlas. It is a pivot joint. The joint has two separate synovial cavities—anterior and posterior.

Ligaments

The lateral atlantoaxial joints are supported by:

a. Capsular ligament all around.
b. Lateral part of the anterior longitudinal ligament.
c. Ligamentum flavum.
d. Accessory atlantoaxial ligament presents between posterior surface of body of axis and lateral masses of atlas vertebra.

The median atlantoaxial joint is strengthened by the following:

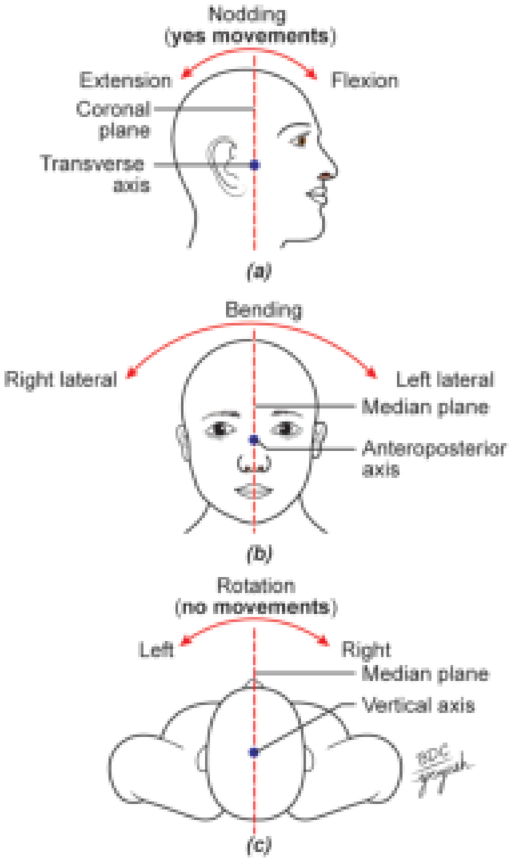
a. The anterior smaller part of the joint between the anterior arch of the atlas and the dens is surrounded by a loose capsular ligament.
b. The posterior larger part of the joint between the dens and transverse ligament (often called a bursa) is often continuous with one of the atlanto-occipital joints. Its main support is the transverse ligament which forms a part of the cruciform ligament of the atlas.

The *transverse ligament* is attached on each side to the medial surface of the lateral mass of the atlas. In the median plane, its fibres are prolonged upwards to the basiocciput and downwards to the body of the axis, thus forming the *cruciform ligament of the atlas vertebra*. The transverse ligament embraces the narrow neck of the dens, and prevents its dislocation.

Movements (Figs 9.16a to c)

Movements at all three joints are rotatory and take place around a vertical axis. The dens forms a pivot around which the atlas rotates (carrying the skull with it). The movement is limited by the alar ligaments.

The rotatory movements are brought about by the obliquus capitis inferior, the rectus capitis posterior major and the splenius capitis of one side, acting with the sternocleidomastoid of the opposite side.


Nodding
(yes movements)
Extension
Flexion
Coronal plane
Transverse axis
(a)
Bending
Right lateral
Left lateral
Median plane
Anteroposterior axis
(b)
Rotation
(no movements)
Left
Right
Median plane
Vertical axis
(c)

Figs 9.16a to c: Various movements of the neck

Ligaments Connecting Axis with Occipital Bone

These ligaments are the membrana tectoria, the cruciate ligament, the apical ligament of the dens and the alar ligaments. They support both the atlanto-occipital and atlantoaxial joints.

1. ***Membrana tectoria*** is an upward continuation of the posterior longitudinal ligament. It lies posterior to the transverse ligament. It is attached inferiorly to the posterior surface of the body of the axis and superiorly to the basiocciput (within the foramen magnum).
2. ***Cruciate ligament*** (*see* transverse ligament).
3. The *apical ligament of the dens* extends from the apex of the dens to the basiocciput inferior to the attachment of the cruciate ligament. It is the continuation of the notochord.
4. ***Alar ligament***, one on each side, extends from the upper part of the lateral surface of the dens to the medial surface of the occipital condyles. These are strong ligaments that limit the rotation and flexion of the head. They are relaxed during extension.

CLINICAL ANATOMY

- Death in execution by ***hanging*** is due to dislocation of the dens following rupture of the transverse ligament of the dens, which then crushes the spinal cord and medulla. However, hanging can also cause fracture through the axis, or separation of the axis from the third cervical vertebra (Fig. 9.17).
- ***Hangman's fracture*** is the fracture of pedicles of axis vertebra (Fig. 9.18). It may occur in automobile accidents or fall from height.
- ***Cervical spondylosis:*** Injury or degenerative changes of old age may rupture the thin lateral parts of the annulus fibrosus (of the intervertebral disc) resulting in prolapse of the nucleus pulposus. This is known as disc prolapse or spondylosis and may be lateral or median. Although, it is commonest in the lumbar region, it may occur in the lower cervical region. This causes shooting pain along the distribution of the cervical nerve pressed. A direct posterior prolapse may compress the spinal cord (Fig. 9.19).
- Cervical vertebrae may be fractured, or dislocated by a fall on the head with acute flexion of the neck. In the cervical region, the vertebrae can dislocate without any fracture of the articular processes due to their horizontal position.
- Pithing of frog takes place when the cruciate ligament of median atlantoaxial joint ruptures, crushing the vital centres in medulla oblongata, resulting in immediate death. This occurs in judicial hanging as well.
- The degenerative changes or spondylitis may occur in the cervical spine, leading to narrowed intervertebral foramen, causing pressure on the spinal nerves (Fig. 9.20).

Competency:
AN29.5 Describe and demonstrate attachments of: Scalenus anterior and scalenus medius

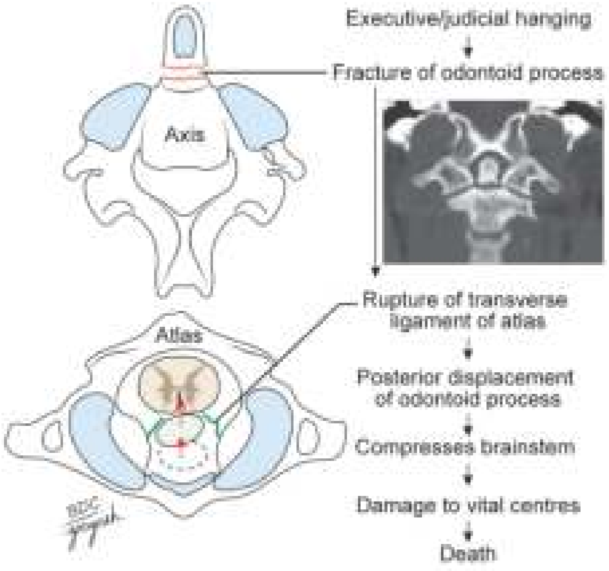

Executive/judicial hanging
Fracture of odontoid process
Axis
Rupture of transverse ligament of atlas
Atlas
Posterior displacement of odontoid process
Compresses brainstem
Damage to vital centres
Death

Fig. 9.17: Fracture of the dens during hanging

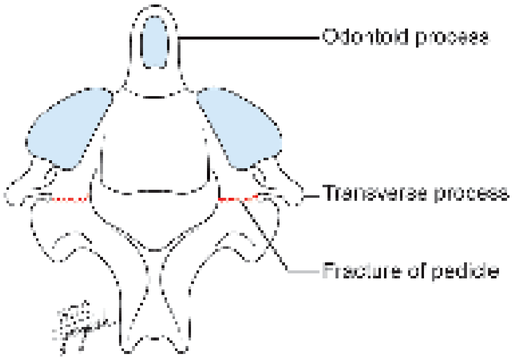


Fig. 9.18: Hangman's fracture

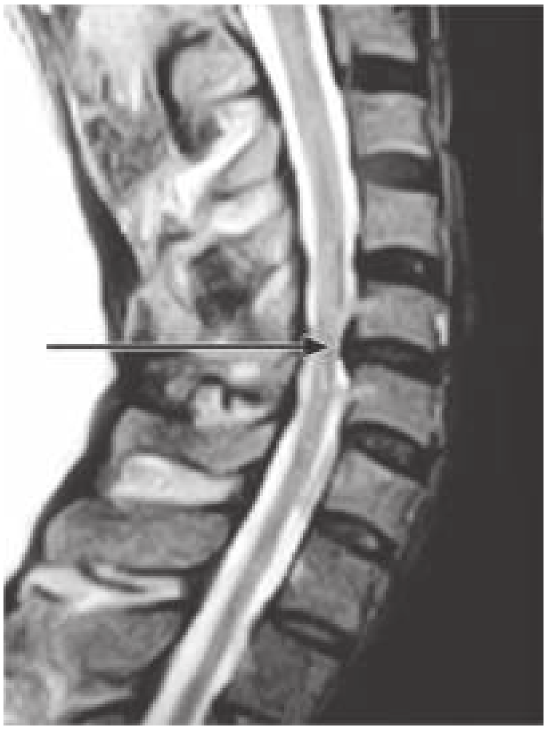


Fig. 9.19: Posterior intervertebral disc prolapse

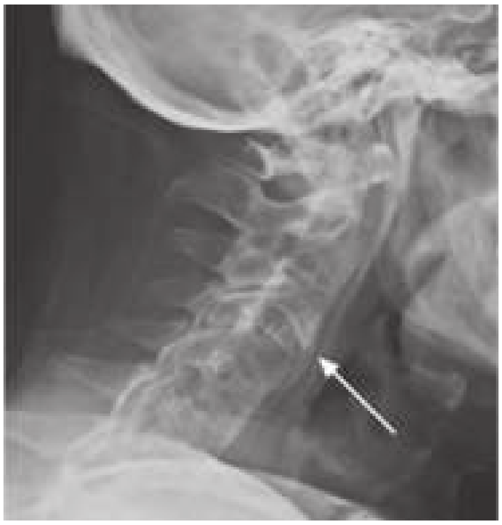


Fig. 9.20: Spondylitis

Facts to Remember

- Vertebral artery comprises four parts:
  a. First part in neck
  b. Second part in forearm transversaria of C6 to C1 vertebrae
  c. Third part on the posterior arch of atlas
  d. Fourth part through foramen magnum in the cranial cavity.
- Apical ligament is a remnant of notochord
- Median atlantoaxial joint is a pivot type of joint, permitting movement of ‘No’
- Atlanto-occipital joint is an ellipsoid joint permitting movement of ‘Yes’
- Transverse ligament of atlas is part of the cruciate ligament. It keeps the dens of axis in position.

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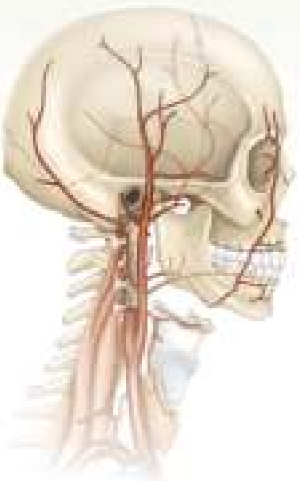
1. Relations of vertebral artery
2. Cervical pleura
3. Further reading
4. Viva voce questions



Chapter

10

Back of the Neck

The back of the neck extends from external occipital protuberance and superior nuchal line above and spine of C7 vertebra and horizontal line passing through the acromion processes of both scapulae below. Important structures of back of neck are as follows:

1. Ligamentum nuchae
2. Extensor muscles of neck
3. Suboccipital triangle
4. Arterial anastomosis around the semispinalis capitis
5. 3rd part of vertebral artery.

SURFACE LANDMARKS

1. *External occipital protuberance*: It is a bony prominence felt at the upper end of nuchal furrow. It demarcates the junction of head and neck (Fig. 10.1).
2. *Nuchal furrow*: It is a vertical groove in the midline on the back of neck.
3. *Superior nuchal lines*: These are upward arched bony lines extending laterally from the external occipital protuberance.
4. *Spine of 7th cervical vertebra*: It is a round, bony projection at the lower end of nuchal furrow (Fig. 10.1).

   Note: Spine of other cervical vertebrae are covered by ligamentum nuchae, hence they cannot be felt.
5. *Acromion process*: It can be felt as a bony edge at the summit of the shoulder (*akros* = highest and *omos* = shoulder in Greek) (Fig. 10.1).

LAYERS OF BACK OF THE NECK

The layers of back of the neck are as follows:

1. Skin
2. Superficial fascia
3. Deep fascia
4. Muscle

SKIN OF BACK OF THE NECK

The skin of the nape or back of the neck, and of the back of the scalp is supplied by medial branches of the dorsal rami of C2 the *greater occipital nerve;* C3 the *third occipital nerve*. Each posterior primary ramus divides into a medial branch and a lateral branch, both of which supply the intrinsic muscles of the back.

The medial branch in this region supplies the skin as well. The *dorsal ramus of C1* does not divide into medial and lateral branches, and is distributed only to the muscles bounding the suboccipital triangle.

SUPERFICIAL FASCIA

The superficial fascia of the back is thick and tough. It contains cutaneous nerves and vessels. The cutaneous nerves include greater occipital, third occipital, and cutaneous branches of C4 and C5 nerves. The superficial fascia also contains occipital artery and minute branch from the second part of vertebral artery.

DEEP FASCIA

The deep fascia of back is having two components:

1. *Investing layer of deep cervical fascia* which encloses the trapezius posteriorly.
2. Ligamentum nuchae.

Ligamentum Nuchae

The *ligamentum nuchae* is a triangular fibrous sheet that separates muscles of the two sides of the neck.

Ligamentum nuchae comprises:

- Superior border—attached to external occipital crest.
- Anterior border—attached to posterior tubercles of atlas and spines of C2–C7 vertebrae.
- Free posterior border lies between external occipital protuberance and spine of C7.

Note: Ligamentum nuchae is not a ligament of neck as it does not connect the adjacent bone and it does not have structure of typical ligament [*Reference* 42nd edn. *Grey's Anatomy*]. *Previous concept:* Ligamentum nuchae is a fibroelastic sheet. *Recent concept:* The ligamentum nuchae has two parts:

Dorsal median raphe and median fascial septum.

Median fascial septum lies deep to the dorsal raphe. It extends from the dorsal raphe to the vertebral column, up to the tips of spines of cervical vertebrae. Superiorly, it is attached to the external occipital crest and posterior tubercle of atlas. Median fascial septum does not give rise to any muscle.

DISSECTION

Extend the incision from external occipital protuberance (i), to the spine of the seventh cervical vertebra (Fig. 10.1). Give a horizontal incision from spine of 7th cervical vertebra or vertebra prominens (iv), till the acromion process (v). This will expose the upper part and apex of posterior triangle of neck. Look for the occipital artery at its apex.

Extend the incision from vertebra prominens to spine of lumbar 5 vertebra. Reflect the skin laterally along an oblique line from spine of T12 (ii), till the deltoid tuberosity.

Close to the median plane in the superficial fascia are seen the greater occipital nerve and occipital artery.

Cut through trapezius muscle vertically at a distance of 2 cm from the median plane. Reflect it laterally and identify the accessory nerve, superficial branch of transverse cervical artery and ventral rami of 3rd and 4th cervical nerves.

Latissimus dorsi has already been exposed by the students dissecting the upper limb. Otherwise extend the incision from T12 spine till L5 spine. Reflect the skin till lateral side of the trunk and define the margins of broad thin latissimus dorsi. This muscle and trapezius form the first layer of muscles.

The 2nd layer comprises splenius muscle, levator scapulae, rhomboid major, rhomboid minor, serratus posterior superior and serratus posterior inferior muscles. The splenius is the highest of these muscles.

Levator scapulae forms part of the muscular floor of the posterior triangle. It is positioned between scalenus medius below and splenius capitis above. Follow its nerve and blood supply from dorsal scapular nerve and deep branch of transverse cervical artery, respectively.

Spinal root of accessory nerve and fibres from C3 and C4 to trapezius muscle lie on the levator scapulae.

Rhomboid minor and major lie on same plane as levator scapulae. Both are supplied by dorsal scapular nerve (C5).

Deep to the two rhomboid muscles is thin aponeurotic serratus posterior superior muscle from spines of C7 and T1–T2 vertebrae to be inserted into 2nd–5th ribs. Serratus posterior inferior muscle arises from T11 to T12 spines and thoracolumbar fascia and is inserted into 9th–12th ribs.

The 3rd layer is composed of erector spinae or sacrospinalis with its three subdivisions and semispinalis with its three divisions.

Erector spinae arises from the dorsal surface of sacrum and ascends up the lumbar region. There it divides into three subdivisions, the medial one is spinalis—inserted into the spines, the intermediate one is longissimus—inserted into the transverse processes, and the lateral one is iliocostalis—inserted into the ribs. Each of these divisions is made of short parts, fresh slips arising from the area where the lower slips are inserted.

Deep to erector spinae is the semispinalis again made up of three parts: Semispinalis thoracis, semispinalis cervicis, and semispinalis capitis.

Both these muscles are innervated by the dorsal rami of cervical, thoracic, lumbar and sacral nerves.

Muscles of 4th layer are the multifidus, rotatores, interspinales, intertransversarii and suboccipital muscles.

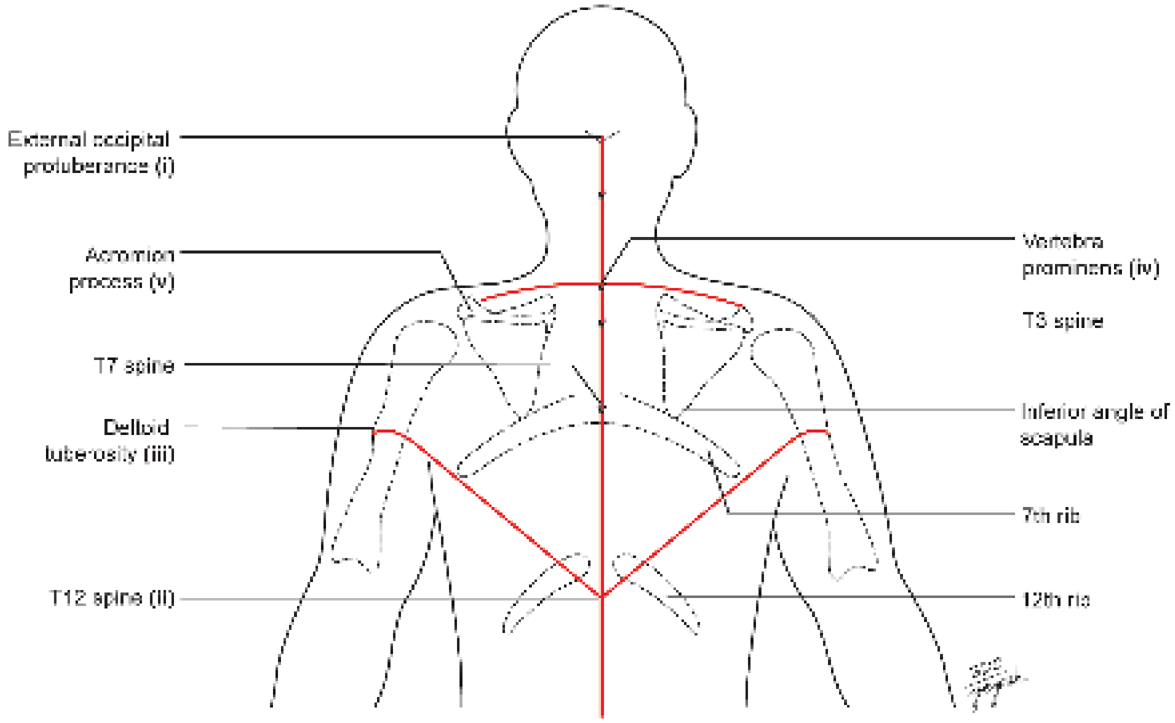


Fig. 10.1: Lines of dissection of back

Competency:
AN42.3 Describe the position, direction of fibres, relations, nerve supply, actions of semispinalis capitis and splenius capitis.

MUSCLES OF THE BACK

The muscles of the back are grouped into the following layers (Flowchart 10.1):

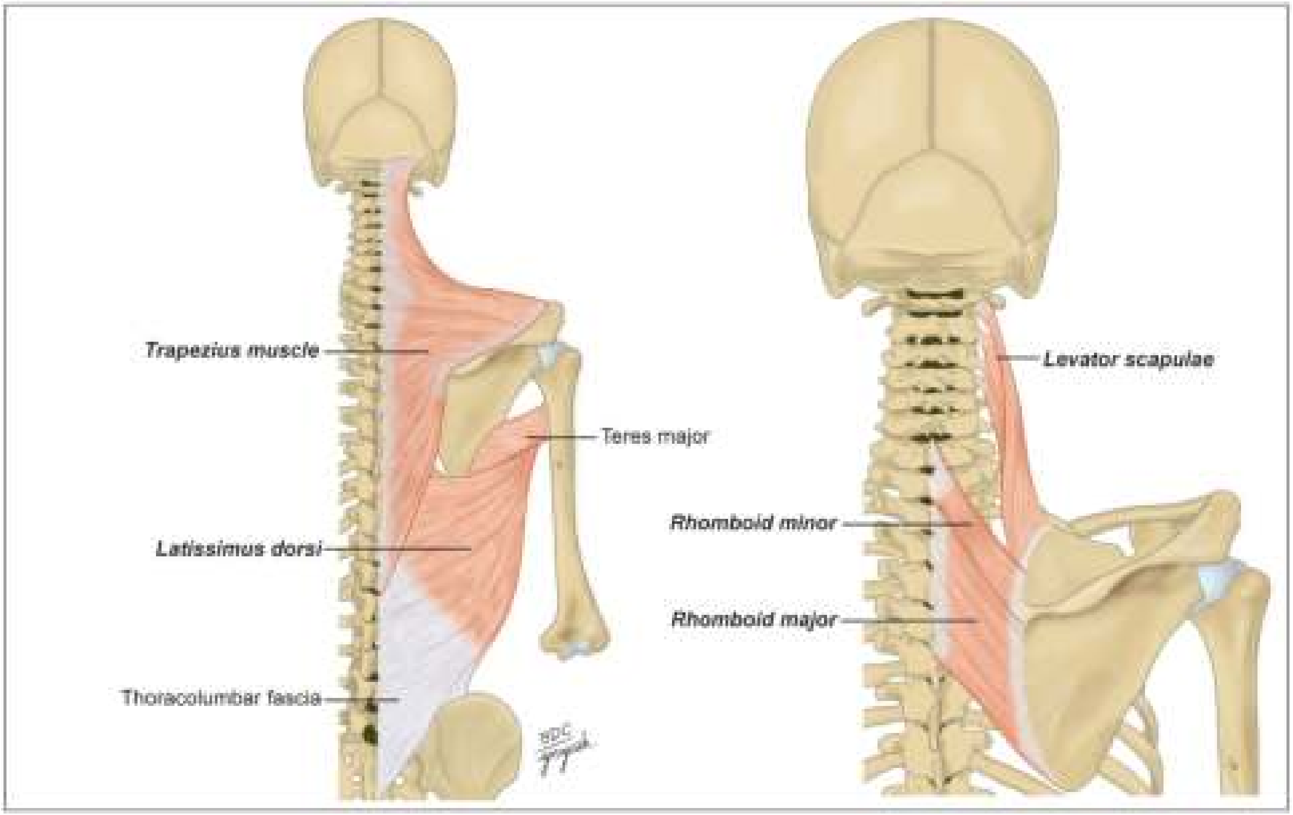
A. ***Immigrant muscles*** (extrinsic or superficial most layers): They are the muscles that connect axial skeleton with the upper limb. They consist of the following (Table 10.1, Plate 10.1):
   1. *First layer*: Trapezius and latissimus dorsi.
   2. *Second layer*: Levator scapulae, rhomboid minor, rhomboid major.
   3. *Third layer*: Serratus posterior superior, serratus posterior inferior (not described here).

B. ***Intrinsic or deep muscles:*** The muscles of these layers are true muscles of the back and are supplied by dorsal rami of spinal nerves. These muscles are arranged in four layers as follows:
   1. *First layer (external layer)*: Splenius capitis, splenius cervicis.
   2. *Second layer (intermediate layer)*: It is group of erector spinae (sacrospinalis) muscles that includes iliocostalis, longissimus, and spinalis.
   3. *Third layer (deep layer)*: Semispinalis, multifidus, rotatores.

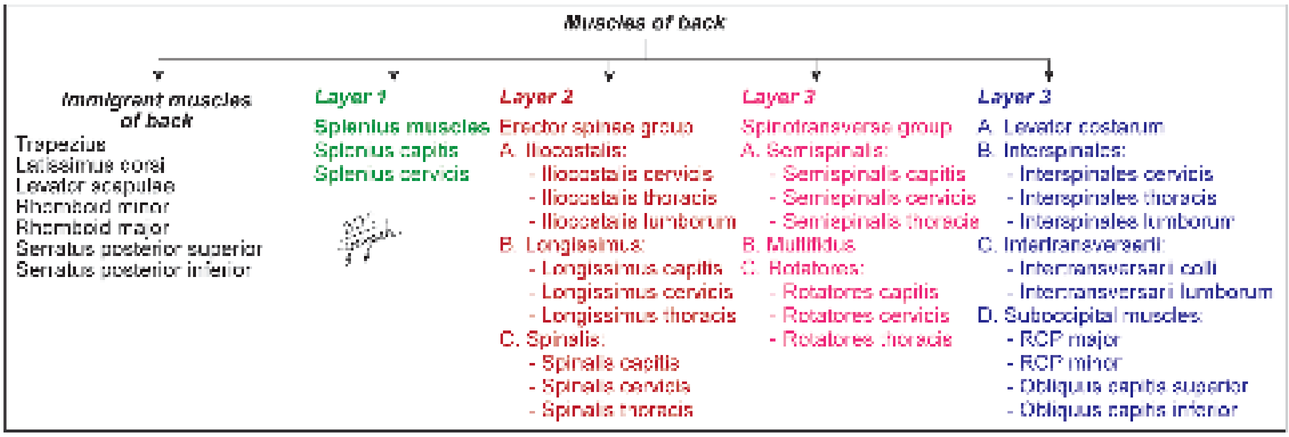
TABLE 10.1: Origin and insertion of muscles connecting the upper limb to the vertebral column – Immigrant axioappendicular muscles of back (extrinsic muscles of back)

Muscle	*Origin*	*Insertion*	*Nerve supply*	*Actions*
Trapezius The right and left muscles together form a trapezium that covers the upper half of the back. Upper fibres descend, lower fibres ascend and middle fibres pass horizontally	• Medial 1/3rd of superior nuchal line • External occipital protuberance • Ligamentum nuchae • C7 spine • T1–T12 spines • Corresponding supraspinous ligaments	• *Upper fibres* into the posterior border of lateral one-third of clavicle and adjacent superior and inferior surfaces • *Middle fibres* into the medial margin of the acromion process and upper lip of the crest of spine of the scapula • *Lower fibres* on the smooth triangular area at the medial end of the spine, with a bursa intervening	• Spinal part of accessory nerve (XI) • Branches from C3, C4	*Upper fibres*: Along with levator scapulae – elevation of scapula (shrugging of shoulder) *Middle fibres*: Along with rhomboid major and minor – retraction of scapula *Lower fibres*: Along with serratus anterior – rotates the scapula in overhead abduction of arm
Latissimus dorsi It covers a large area of the lower back, and is overlapped by the trapezius	• Posterior 1/3rd of the outer lip of iliac crest • Posterior layer of lumbar fascia; thus attaching the muscle to the lumbar and sacral spines • Spines of T7–T12, lower four ribs • Inferior angle of the scapula	The muscle winds round the lower border of the teres major, and forms the posterior fold of the axilla The tendon is twisted upside down and is inserted into floor of the intertubercular sulcus	Thoracodorsal nerve (C6–C8) (nerve to latissimus dorsi)	• Adduction, extension, and medial rotation of the shoulder as in swimming, rowing, climbing, pulling, folding the arm behind the back, and scratching the opposite scapula • Violent expiratory effort like coughing, sneezing, etc. • Climbing muscle
Levator scapulae	• Transverse processes of C1, C2 • Posterior tubercles of the transverse processes of C3, C4	Superior angle and upper part of medial border (up to triangular area) of the scapula	• A branch from dorsal scapular nerve (C5) • Branches from C3, C4	• Elevation of scapula • Steadies the scapula during movements of the arm
Rhomboid minor	• Lower part of ligamentum nuchae • Spines C7 and T1	Base of the triangular area at the root of the spine of the scapula	Dorsal scapular nerve (C5)	Retraction of scapula
Rhomboid major	• Spines of T2–T5 • Supraspinous ligaments	Medial border of scapula below the root of the spine	Dorsal scapular nerve (C5)	Retraction of scapula
Serratus posterior superior	Ligamentum nuchae, spines of T1–T3 vertebrae	Upper borders of 2nd–5th ribs	2nd–5th intercostal nerves	Elevates 2nd–5th ribs
Serratus posterior inferior	Spines of T11–L2 vertebrae	Lower borders of 9th–12th ribs	9th–12th intercostal nerves	Depress the lower ribs

Plate 10.1: Immigrant axioappendicular muscles of back



Flowchart 10.1: Muscles of back


Muscles of back

Immigrant muscles of back
Trapezius
Latissimus dorsi
Levator scapulae
Rhomboid minor
Rhomboid major
Serratus posterior superior
Serratus posterior inferior

Layer 1
Splenius muscles
Splenius capitis
Splenius cervicis

Layer 2
Erector spinae group
A. Iliocostalis:
  - Iliocostalis cervicis
  - Iliocostalis thoracis
  - Iliocostalis lumborum
B. Longissimus:
  - Longissimus capitis
  - Longissimus cervicis
  - Longissimus thoracis
C. Spinalis:
  - Spinalis capitis
  - Spinalis cervicis
  - Spinalis thoracis

Layer 3
Spinotransverse group
A. Semispinalis:
  - Semispinalis capitis
  - Semispinalis cervicis
  - Semispinalis thoracis
B. Multifidus
C. Rotatores:
  - Rotatores capitis
  - Rotatores cervicis
  - Rotatores thoracis

Layer 3
A. Levator costarum
B. Interspinales:
  - Interspinales cervicis
  - Interspinales thoracis
  - Interspinales lumborum
C. Intertransversarii:
  - Intertransversarii colli
  - Intertransversarii lumborum
D. Suboccipital muscles:
  - RCP major
  - RCP minor
  - Obliquus capitis superior
  - Obliquus capitis inferior

(RCP major: Rectus capitis posterior major, RCP minor: Rectus capitis posterior minor)

4. *Fourth layer (deepest layer)*: Levator costarum, interspinales, intertransversarii, suboccipital muscles.

Intrinsic or Deep Muscles of Back

Muscles of First Layer

Splenius muscles (Plate 10.2)

- They are two in number: ***Splenius cervicis*** and ***splenius capitis***.
- These cover the deeper muscles like a bandage.
- *Origin:* From lower half of ligamentum nuchae and spines of upper 6 thoracic vertebrae. These curve in a half spiral fashion and separate into splenius cervicis and splenius capitis.
- *Splenius cervicis* gets inserted into the posterior tubercles of transverse processes of C1–C4 vertebrae. Splenius capitis forms the floor of the posterior triangle and gets inserted into the mastoid process beneath the sternocleidomastoid muscle.
- It is supplied by dorsal rami of C1–C6 nerves.

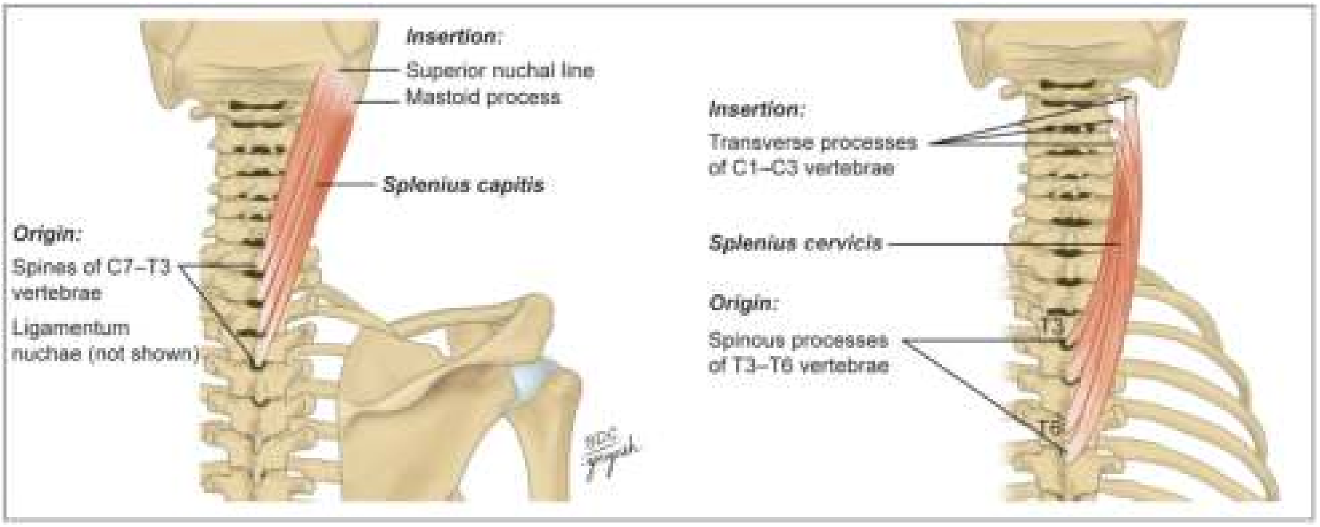
Muscles of Second Layer

It is group of erector spinae (sacrospinalis) muscles that includes iliocostalis, longissimus, and spinalis.

Erector spinae is supplied by posterior rami of the spinal nerves. It extends from the sacrum to the skull.

Origin: Mainly from the back of sacrum between median and lateral sacral crests, from the dorsal segment of iliac

Plate 10.2: Splenius capitis and splenius cervicis


Insertion:
Superior nuchal line
Mastoid process
Splenius capitis
Origin:
Spines of C7–T3 vertebrae
Ligamentum nuchae (not shown)
Insertion:
Transverse processes of C1–C3 vertebrae
Splenius cervicis
Origin:
Spinous processes of T3–T6 vertebrae
T3
T6

crest and related ligaments. Soon it splits into three columns: Iliocostalis, longissimus, and spinalis (Plate 10.3).

1. ***Iliocostalis*** is the lateral column and comprises Plate 10.3:
   a. Iliocostalis lumborum
   b. Iliocostalis thoracis
   c. Iliocostalis cervicis.

   These are short slips and are inserted into angles of the ribs and posterior tubercles of cervical transverse process. Origin of the higher slips is medial to the insertion of the lower slips.
2. ***Longissimus*** is the middle column and is composed of (Plate 10.3):
   a. Longissimus thoracis—inserted into transverse processes of thoracic vertebrae.
   b. Longissimus cervicis—inserted into transverse process of C2–C6 vertebrae.
   c. Longissimus capitis—inserted into mastoid process.
3. ***Spinalis*** is the medial column, extending between lumbar and cervical spines. Its parts are (Plate 10.3):
   a. Spinalis lumborum
   b. Spinalis thoracis
   c. Spinalis cervicis.

Muscles of Third Layer (Plate 10.4)

This layer consists of (Plate 10.4):

1. ***Semispinalis*** extends between transverse processes and spines of the vertebrae. It has three parts:
   a. Semispinalis thoracis
   b. Semispinalis cervicis
   c. Semispinalis capitis.

   It only lies in the upper half of vertebral column. Semispinalis capitis is its biggest component. It arises from transverse processes of C3–T4 vertebrae, passes up next to the median plane, and gets inserted into the medial area between superior and inferior nuchal lines of the occipital bone.
2. ***Multifidus*** is one of the oblique deep muscles. It arises from mammillary process of lumbar vertebrae to be inserted into 2–3 higher spinous processes.
3. ***Rotatores*** are the deepest group. These pass from root of transverse process to the root of the spinous process. These are well developed in thoracic region. It has two components:
   a. Rotatores longi
   b. Rotatores brevis.

Muscles of Fourth Layer (Plate 10.5)

1. ***Levatores costarum*** consists of 12 small triangular muscles that connect the thoracic vertebrae with the adjacent ribs. Located along either side of the posterior aspect of the thoracic vertebra they descend adjacent to the spine, spanning the thoracic region from C7 to T12 levels.
2. ***Interspinales*** muscles are short, paired muscles that belong to the deepest layer of the intrinsic muscles of the back. They extend between adjacent spinous processes of the vertebral column. It has three components:
   a. Interspinales cervicis
   b. Interspinales thoracis
   c. Interspinales lumborum.
3. ***Intertransversarii*** are small muscles of the back found between contiguous transverse processes of the cervical, lumbar, and some thoracic, vertebrae. It has two components:
   a. Intertransversarii colli
   b. Intertransversarii lumborum.
4. ***Suboccipital muscles*** are located inferior to the external occipital protuberance and the inferior nuchal line. These includes four pairs of small muscles:
   a. Rectus capitis posterior major
   b. Rectus capitis posterior minor
   c. Obliquus capitis inferior
   d. Obliquus capitis superior

Plate 10.3: Iliocostalis, longissimus and spinalis muscles

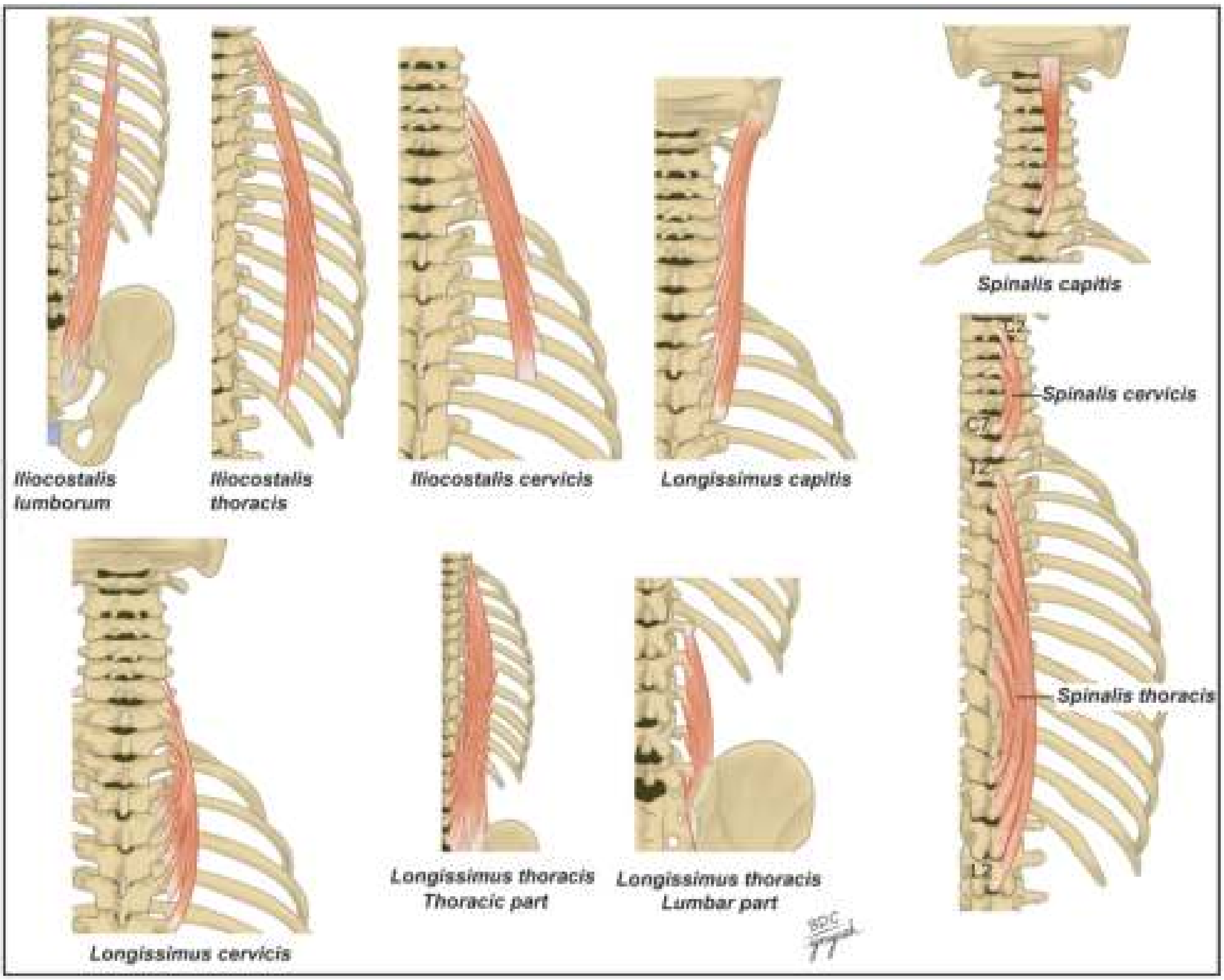
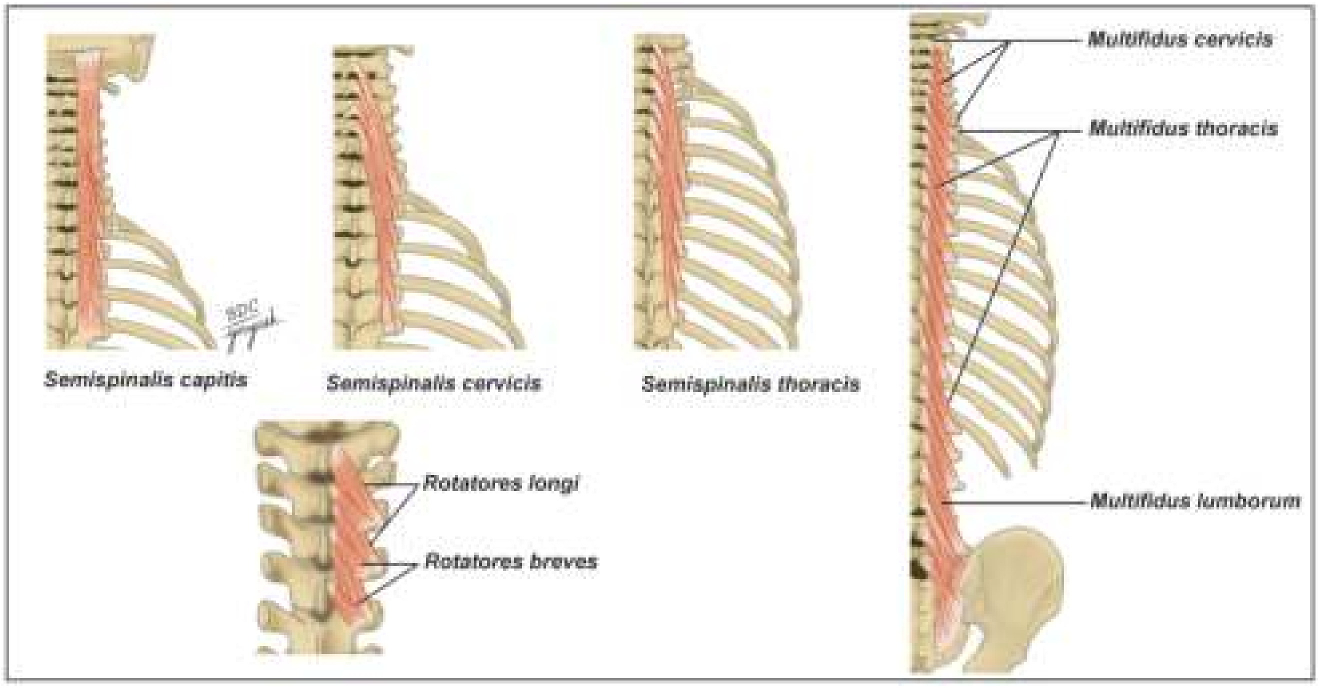

Iliocostalis lumborum
Iliocostalis thoracis
Iliocostalis cervicis
Longissimus capitis
Spinalis capitis
C2
Spinalis cervicis
C7
T2
Spinalis thoracis
L2
Longissimus cervicis
Longissimus thoracis Thoracic part
Longissimus thoracis Lumbar part
SDC

Plate 10.4: Semispinalis, multifidus and rotatores muscles


Semispinalis capitis
SDC
Semispinalis cervicis
Semispinalis thoracis
Multifidus cervicis
Multifidus thoracis
Multifidus lumborum
Rotatores longi
Rotatores breves

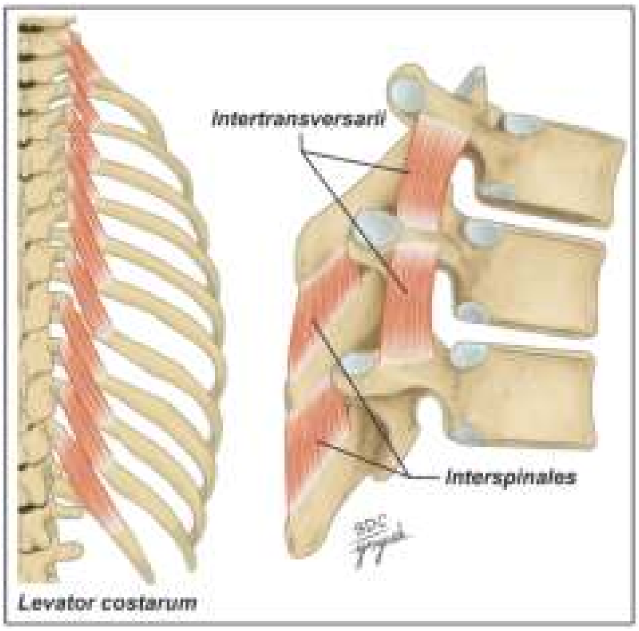


Plate 10.5: Levator costarum, interspinales and intertransversarii

SUBOCCIPITAL REGION

The suboccipital region is located deep in the upper part of the neck (Table 10.2, Plate 10.6).

Boundaries

Above: Inferior nuchal line

Below: Spine and laminae of axis vertebra

Laterally: Mastoid process and transverse processes of atlas and axis vertebrae.

In this region, the following structures are present:

1. Suboccipital muscles
2. Suboccipital triangle and its contents.

Exposure of Suboccipital Triangle

To expose the suboccipital triangle, the following structure or layers need to be reflected:

1. Skin
2. Superficial fascia
3. Cutaneous nerves and vessels: Greater and 3rd occipital nerves, occipital artery
4. Trapezius medially and sternocleidomastoid laterally
5. Splenius capitis
6. Semispinalis capitis and longissimus capitis.

Suboccipital Muscles

The origin, insertion, nerve supply and actions of suboccipital muscles are described in Table 10.2.

The suboccipital triangle is a muscular space situated deep in the suboccipital region.

Competency:
AN42.2 Describe and demonstrate the boundaries and contents of suboccipital triangle.

SUBOCCIPITAL TRIANGLE

The suboccipital triangle is a triangular intermuscular space located deep in the suboccipital region (Fig. 10.2, Flowchart 10.2).

Boundaries

Superomedially

Rectus capitis posterior major muscle supplemented by the *rectus capitis posterior minor*.

Superolaterally

Obliquus capitis superior muscle.

Inferiorly

Obliquus capitis inferior muscle.

Roof

1. *Medially:* Dense fibrous tissue covered by the semispinalis capitis.
2. *Laterally:* Longissimus capitis and occasionally the splenius capitis.

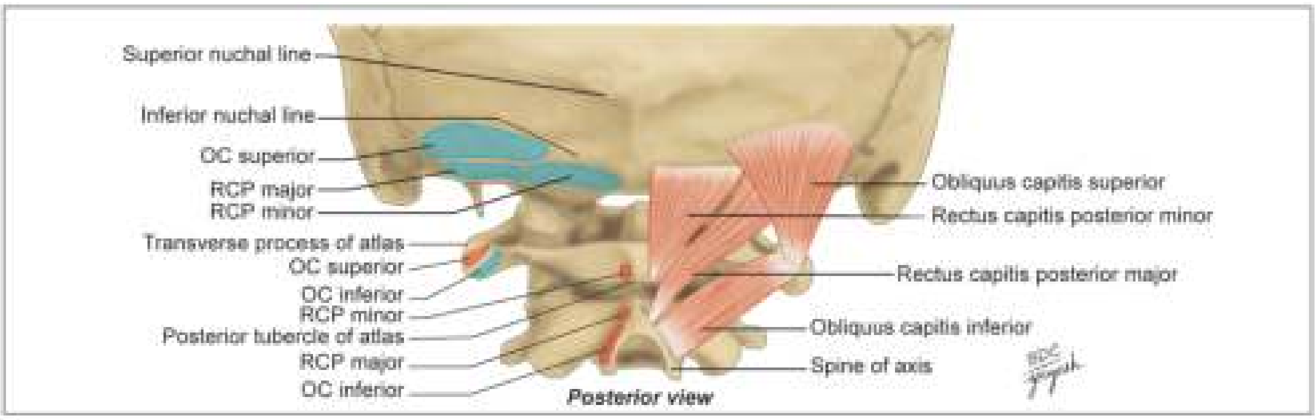
Floor

1. Posterior arch of atlas.
2. Posterior atlanto-occipital membrane.

TABLE 10.2: Origin, insertion, nerve supply and actions of suboccipital muscles
(*Note*: All the suboccipital muscles are supplied by dorsal ramus of C1 nerve, i.e. suboccipital nerve)

Muscle	*Origin*	*Insertion*	*Actions*
1. **Rectus capitis posterior major**	Spine of axis	Lateral part of the area below the inferior nuchal line	1. Mainly postural 2. Acting alone, it turns the chin to the same side 3. Acting together, the two muscles extend the head
2. **Rectus capitis posterior minor**	Posterior tubercle of atlas	Medial part of the area below the inferior nuchal line	1. Mainly postural 2. Extends the head
3. **Obliquus capitis superior** (superior oblique)	Transverse process of atlas	Lateral area between the nuchal lines	1. Mainly postural 2. Extends the head 3. Flexes the head laterally
4. **Obliquus capitis inferior** (inferior oblique)	Spine of axis	Transverse process of atlas	1. Mainly postural 2. Turns chin to the same side

Plate 10.6: Suboccipital muscles (posterior view)


Superior nuchal line
Inferior nuchal line
OC superior
RCP major
RCP minor
Transverse process of atlas
OC superior
OC inferior
RCP minor
Posterior tubercle of atlas
RCP major
OC inferior
Posterior view
Obliquus capitis superior
Rectus capitis posterior minor
Rectus capitis posterior major
Obliquus capitis inferior
Spine of axis

(OC inferior: Obliquus capitis inferior, OC superior: Obliquus capitis superior, RCP major: Rectus capitis posterior major, RCP minor: Rectus capitis posterior minor)

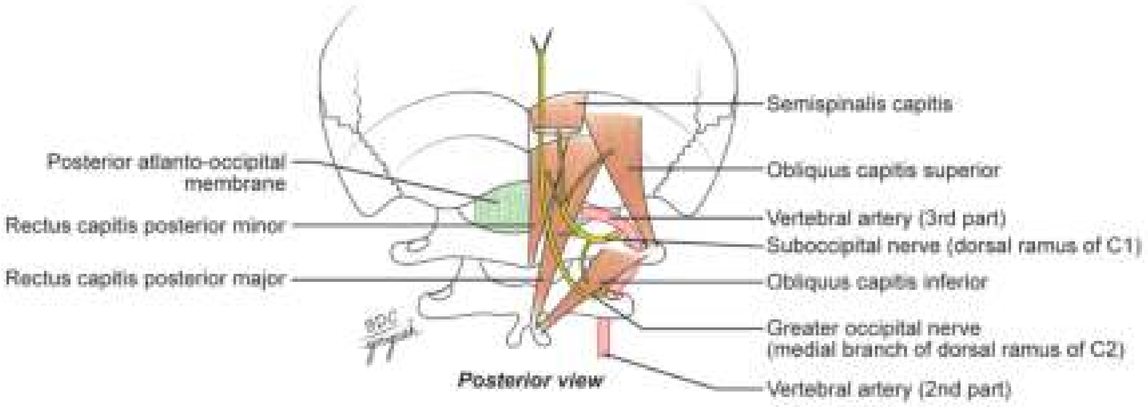
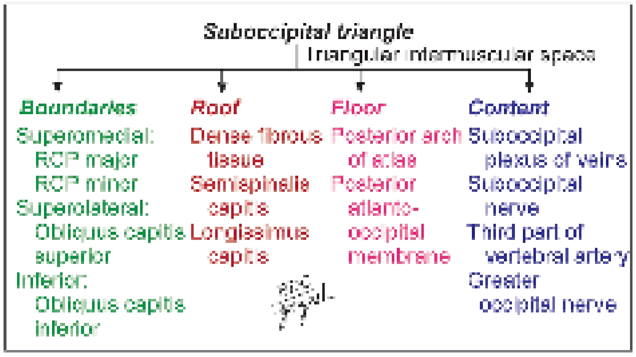

Posterior atlanto-occipital membrane
Rectus capitis posterior minor
Rectus capitis posterior major
Posterior view
Semispinalis capitis
Obliquus capitis superior
Vertebral artery (3rd part)
Suboccipital nerve (dorsal ramus of C1)
Obliquus capitis inferior
Greater occipital nerve (medial branch of dorsal ramus of C2)
Vertebral artery (2nd part)

Fig. 10.2: Suboccipital triangle: Boundaries, floor and contents

Flowchart 10.2: Suboccipital triangle


Suboccipital triangle
Triangular intermuscular space
Boundaries
Superomedial:
RCP major
RCP minor
Superolateral:
Obliquus capitis superior
Inferior:
Obliquus capitis inferior
Roof
Dense fibrous tissue
Semispinalis capitis
Longissimus capitis
Floor
Posterior arch of atlas
Posterior atlanto-occipital membrane
Content
Suboccipital plexus of veins
Suboccipital nerve
Third part of vertebral artery
Greater occipital nerve

Note:

Vertebral artery: It is the first and largest branch of the first part of the subclavian artery. Its only the third part appears in the suboccipital triangle (Fig. 10.3). This part appears at the foramen transversarium of the atlas, grooves the atlas, and leaves the triangle by passing deep to the lateral edge of the posterior atlanto-occipital membrane. The artery is separated from the posterior arch of the atlas by the first cervical nerve and its dorsal and ventral rami (For details, *see* Chapter 9).

Suboccipital plexus of veins lies in and around the suboccipital triangle, and drains the muscular, occipital veins, the internal vertebral venous plexus, and the condylar emissary vein. It itself drains into the deep cervical and vertebral plexus of veins.

Greater occipital nerve is the larger medial branch of the dorsal ramus of the second cervical nerve. It is the *thickest cutaneous nerve* in the body. It crosses the suboccipital triangle and pierces the semispinalis capitis and trapezius muscles to ramify on the back of the head reaching up to the vertex. It supplies the semispinalis capitis in addition to the scalp (Fig. 10.2).

Third occipital nerve is the slender medial branch of the dorsal ramus of the third cervical nerve. After piercing the semispinalis capitis and the trapezius, it ascends medial to the greater occipital nerve. It supplies the skin to the back of the neck up to the external occipital protuberance.

Deep cervical artery is a branch of the costocervical trunk of the subclavian artery. It passes into the back of the neck just above the neck of the 1st rib. It ascends deep to the *semispinalis capitis* and anastomoses with the descending branch of the occipital artery.

Contents

1. Suboccipital plexus of veins
2. Suboccipital nerve (dorsal ramus of C1 nerve)
3. Third part of vertebral artery
4. Greater occipital nerve (medial branch of dorsal ramus of C2).

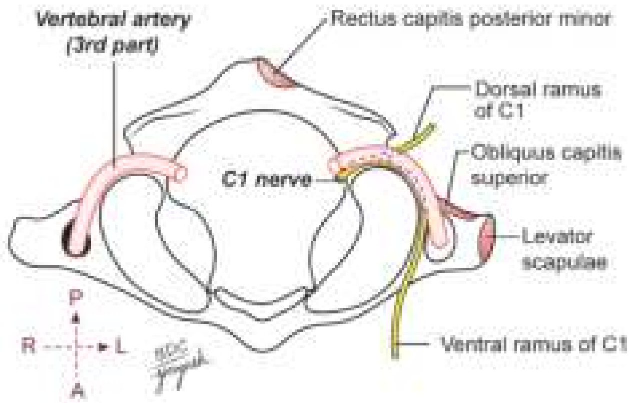

Vertebral artery (3rd part)
Rectus capitis posterior minor
Dorsal ramus of C1
C1 nerve
Obliquus capitis superior
Levator scapulae
Ventral ramus of C1
P
R
L
A

Fig. 10.3: Relationship of the vertebral artery to the atlas vertebra and to the first cervical nerve, as seen from above

OCCIPITAL ARTERY

It arises from the external carotid artery, opposite the origin of the facial artery. It runs backwards and upwards deep to the lower border of the posterior belly of the digastric, crossing the carotid sheath, and the accessory and hypoglossal nerves. Next it runs deep to the mastoid process and to the muscles attached to it—the sternocleidomastoid, digastric, splenius capitis and longissimus capitis. The artery then crosses the rectus capitis lateralis, the obliquus capitis superior and the semispinalis capitis muscles at the apex of the posterior triangle. Finally, it pierces the trapezius 2.5 cm from the midline and comes to lie along the greater occipital nerve. In the superficial fascia of the scalp, it has a tortuous course.

Its branches in this region are:

a. Mastoid
b. Meningeal
c. Muscular.

SUBOCCIPITAL NERVE

The suboccipital nerve is the *dorsal ramus of C1 nerve*. It emerges backward between the vertebral artery and the posterior arch of atlas (Fig. 10.4). It ends by giving 5 muscular branches to the following muscles:

1. Rectus capitis posterior major
2. Rectus capitis posterior minor
3. Obliquus capitis superior
4. Obliquus capitis inferior
5. Semispinalis capitis

The branch to oblique capitis inferior gives a communicating branch to the greater occipital nerve.

Note: Suboccipital nerve does not give any subcutaneous branch. Ventral primary ramus of C1 nerve joins the ventral ramus of C2 nerve and takes part in the formation of cervical plexus.

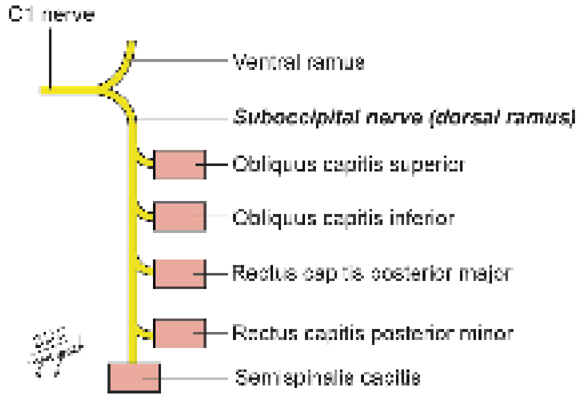

C1 nerve
Ventral ramus
Suboccipital nerve (dorsal ramus)
Obliquus capitis superior
Obliquus capitis inferior
Rectus capitis posterior major
Rectus capitis posterior minor
Semispinalis capitis

Fig. 10.4: Suboccipital nerve (dorsal ramus)

CLINICAL ANATOMY

- ***Neck rigidity***, seen in cases with meningitis, is due to spasm of the extensor muscles. This is caused by irritation of the nerve roots during their passage through the subarachnoid space which is infected. Passive flexion of neck and straight leg raising test cause pain as the nerves are stretched (Figs 10.5 and 10.6).
- ***Cisternal puncture*** is done when lumbar puncture fails. The patient either sits up or lies down in the left lateral position. A needle is introduced in the midline above the spine of axis in forward and upward direction parallel to an imaginary line extending from external acoustic meatus to nasion. It passes through the posterior atlanto-occipital membrane between the posterior arch of atlas and the posterior margin of foramen magnum. The needle enters the cerebellomedullary cistern and small amount of CSF is withdrawn.
- Neurosurgeons approach the posterior cranial fossa through this region.

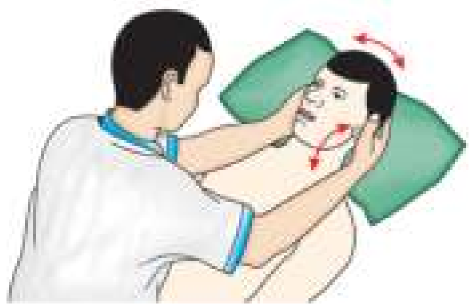


Fig. 10.5: Passive flexion of neck

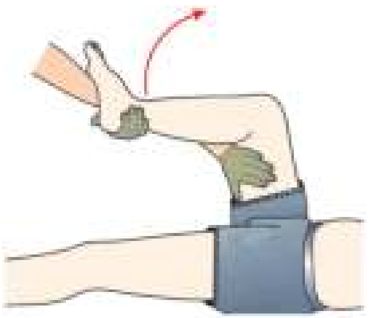


Fig. 10.6: Straight leg raising test causes pain in meningitis

DISSECTION

It is deep triangle in the area between the occiput and the spine of 2nd cervical (the axis) vertebra. The deepest muscles are the muscles of suboccipital triangle.

Cut the attachments of trapezius from superior nuchal line and reflect it towards the spine of scapula. Cut the splenius capitis from its attachment on the mastoid process and reflect it downwards. Clean the superficial fascia over the semispinalis capitis medially and longissimus capitis laterally. Reflect longissimus capitis downwards from the mastoid process.

Cut through semispinalis capitis and turn it towards lateral side. Define the boundaries and contents of the suboccipital triangle.

VIDEO

Video 3.10 **Muscles of the Back**

Facts to Remember

- Artery lying on posterior arch of atlas is the third part of vertebral artery.
- Greater occipital nerve is the thickest cutaneous nerve of the body.
- The spinal process of C7 vertebra can be palpated at the root of the neck on the back.
- Suboccipital nerve does not give any subcutaneous branch.

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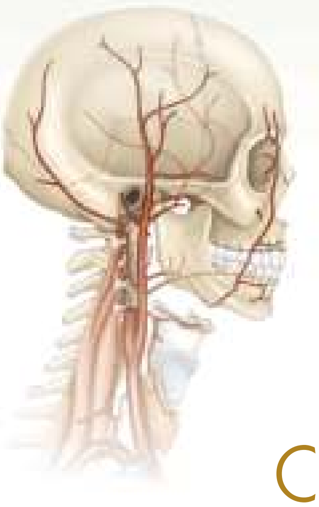
1. Intrinsic muscles of the back – first or external layer
2. Intrinsic muscles of the back – second or intermediate layer
3. Intrinsic muscles of the back – third or deep layer
4. Intrinsic muscles of neck – fourth or deepest layer
5. Further reading
6. Viva voce questions



Chapter

11

Contents of Vertebral Canal

VERTEBRAL CANAL

When the vertebrae are put in a sequence, their vertebral foramina lie one below the other forming a continuous canal which is called the *vertebral canal.* This canal contains the three meninges with their spaces and the spinal cord including the cauda equina. The intervertebral foramina are a pair of foramina between the pedicles of the adjacent vertebrae. Each foramen contains dorsal and ventral roots, trunk and dorsal and ventral primary rami of the spinal nerve, and spinal vessels.

Competency:
AN42.1 Describe the contents of the vertebral canal.

CONTENTS

The vertebral canal contains the following structures from without inwards (Fig. 11.1).

1. Epidural or extradural space
2. Thick dura mater or pachymeninx
3. Subdural capillary space
4. Delicate arachnoid mater
5. Wide subarachnoid space containing cerebrospinal fluid (CSF)
6. Firm pia mater. The arachnoid and pia together form the leptomeninges.
7. Spinal cord or spinal medulla and the cauda equina.

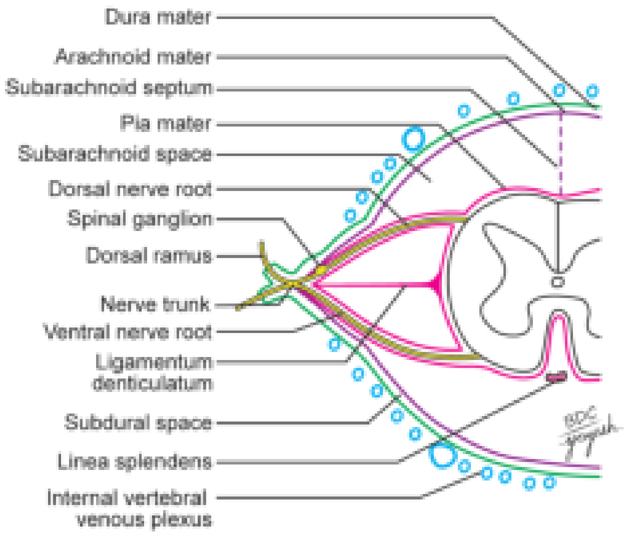


Fig. 11.1: Schematic transverse section showing the spinal meninges

Note: The spinal cord is considered along with the brain in Chapter 5, *BD Chaurasia's Human Anatomy*, *Volume 4*. The other contents are described below.

DISSECTION

Clean the spines and laminae of the entire vertebral column by removing all the muscles attached to them. Trace the dorsal rami of spinal nerves towards the intervertebral foramina. Saw through the spines and laminae of the vertebrae carefully and detach them so that the spinal medulla/spinal cord encased in the meninges becomes visible.

Clean the external surface of dura mater enveloping the spinal cord by removing fat and epidural plexus of veins. Carefully cut through a small part of the dura mater by a fine median incision. Extend this incision above and below. See the delicate arachnoid mater. Incise it. Push the spinal cord to one side and try to identify the ligamentum denticulatum. Define the attachments of the dorsal and ventral nerve roots on the surface of spinal cord and their union to form the trunk of the spinal nerve. Cut the trunk of all spinal nerves on both the sides. Gently pull the spinal cord with cauda equina out from the vertebral canal.

Epidural Space

Epidural space lies between the spinal dura mater, and the periosteum with ligaments lining the vertebral canal.

It contains:

a. Loose areolar tissue
b. Semiliquid fat
c. Spinal arteries on their way to supply the deeper contents
d. Internal vertebral venous plexus.

The ***spinal arteries*** arise from different sources at different levels; they enter the vertebral canal through the intervertebral foramina, and supply the spinal cord, the spinal nerve roots, the meninges, the periosteum and ligaments.

Venous blood from the spinal cord drains into the epidural or internal vertebral plexus.

Spinal Dura Mater

Spinal dura mater is a thick, tough fibrous membrane which forms a loose sheath around the spinal cord (Fig. 11.2). It is continuous with the meningeal layer of the cerebral dura mater. The spinal dura extends from the foramen magnum to the lower border of the second sacral vertebra; whereas the spinal cord ends at the lower border of first lumbar vertebra. The dura gives tubular prolongations to the dorsal and ventral nerve roots and to the spinal nerves as they pass through the intervertebral foramina.

Subdural Space

Subdural space is a capillary or potential space between the dura and the arachnoid, containing a thin film of serous fluid. This space permits movements of the dura over the arachnoid. The space is continued for a short distance onto the spinal nerves and is in free communication with the lymph spaces of the nerves.

Arachnoid Mater

Arachnoid mater is a thin, delicate and transparent membrane that loosely invests the entire central nervous system (Fig. 11.2). Inferiorly, it extends, like the dura up to the lower border of the second sacral vertebra. It is adherent to the dura only where some structures pierce the membrane and where the ligamentum denticulata are attached to the dura mater.

Subarachnoid Space

Subarachnoid space is a wide space between the pia and the arachnoid, filled with ***cerebrospinal fluid*** (**CSF**). It surrounds the brain and spinal cord like a water cushion. The spinal subarachnoid space is wider than the space around the brain. It is widest below the lower end of the spinal cord where it encloses the cauda equina.

Note: ***Lumbar puncture*** is usually done in the lower widest part of the space, between 3rd and 4th lumbar vertebrae (Fig.11.3)

Spinal Pia Mater (Figs 11.1 and 11.2)

1. Spinal pia mater is thicker, firmer, and less vascular than the cerebral pia, but both are made up of two layers:
   a. Outer ***epi-pia*** containing larger vessels.
   b. Inner ***pia-glia*** *or pia-intima* which is in contact with nervous tissue.

   Between the two layers, there are many small blood vessels and also cleft-like spaces which communicate with the subarachnoid space. The pia mater closely invests the spinal cord, and is continued below the spinal cord as the ***filum terminale***.
2. Posteriorly, the pia is adherent to the posterior median septum of the spinal cord, and is also connected to the arachnoid by a fenestrated ***subarachnoid septum***.
3. Anteriorly, the pia is folded into the anterior median fissure of the spinal cord. It thickens at the mouth of the fissure to form a median, longitudinal glistening band, called the ***linea splendens*** (Fig. 11.1).
4. On each side between the ventral and dorsal nerve roots, the pia forms a narrow vertical ridge, called the ***ligamentum denticulatum*** (***Fig. 11.2***). This is so-called because it gives off a series of triangular tooth-like processes which project from its lateral free border. Each ligament has 21 processes; the first at the level of the foramen magnum, and the last between twelfth thoracic and first lumbar spinal nerves. Each process passes through the arachnoid to the dura between two *adjacent spinal nerves*. The processes suspend the spinal cord in the middle of the subarachnoid space.
5. The ***filum terminale*** is a delicate, thread-like structure about 20 cm long. It extends from the apex of the conus medullaris to the dorsum of the first piece of the coccyx. It is composed chiefly of pia mater, although a few nerve fibres rudiments of 2nd and 3rd coccygeal nerves are found adherent to the upper part of its outer surface. The central canal of the spinal cord extends into it for about 5 mm.
6. The filum terminale is subdivided into a part lying within the dural sheath called the ***filum terminale internum***; and a part lying outside the dural sheath, below the level of the second sacral vertebra called the ***filum terminale externum***. The filum terminale internum is 15 cm long, and the externum is 5 cm long.
7. ***Pial sheaths*** surround the nerve roots crossing the subarachnoid space, and the vessels entering the substance of the spinal cord.

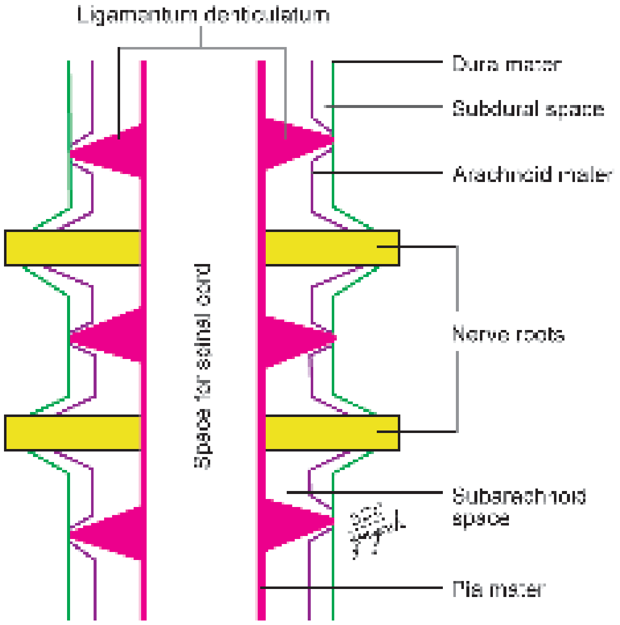


Fig. 11.2: Ligamentum denticulatum and its relationship to the dura mater and to the arachnoid mater

CLINICAL ANATOMY

- ***Leptomeningitis:*** Inflammation due to infection of leptomeninges, i.e. pia mater and arachnoid mater is known as ***meningitis***. This is commonly tubercular or pyogenic. It is characterized by fever, marked headache, neck rigidity, often accompanied by delirium and convulsions, and a changed biochemistry of CSF. CSF pressure is raised, its proteins and cell contents are increased, and sugars and chloride are selectively diminished.
- ***Lumbar puncture in adult:*** Patient is lying on side with maximally flexed spine. A line is taken between highest points of iliac spine at L4 level. Skin locally anaesthetized, and lumbar puncture needle with trocar inserted carefully between L3 and L4 spines. Needle courses through skin, fat, supraspinous and interspinous ligaments, ligamentum flava, epidural space, dura, arachnoid, subarachnoid space to release CSF (Fig. 11.3).
- ***Lumbar puncture in infant/children:*** During 2nd month of life, spinal cord usually reaches L3 level. Lumbar puncture needle is introduced in flexed spine between L4 and L5.
- ***Cisternal puncture:*** This procedure is rather difficult and dangerous. Cerebellomedullary cistern is approached through posterior atlanto-occipital membrane.
- ***Lumbar epidural:*** The epidural space is the space between vertebral canal and dura mater. The epidural space is deeper in the midline. The procedure is same as lumbar puncture, the needle should reach only in the epidural space and not deep to it in the dura mater. Epidural space is utilized for giving anaesthesia or analgesia (Fig. 11.4).
- ***Caudal epidural:*** The needle is passed through sacral hiatus, which lies equidistant from the right and left posterior superior iliac spines. The needle passes through posterior sacrococcygeal ligament and enters the sacral canal. Then the hub of needle is lowered so that it passes along sacral canal. This space lies below S2 (Fig. 11.3).

SPINAL NERVES

The spinal cord gives rise to 31 pairs of *spinal nerves:* Eight cervical, twelve thoracic, five lumbar, five sacral, and one coccygeal. Each nerve is attached to the cord by two roots—ventral motor and dorsal sensory. Each dorsal nerve root bears a ganglion. The ***ventral and dorsal nerve roots*** unite in the intervertebral foramen to form the ***nerve trunk*** which soon divides into ***ventral and dorsal rami*** (Fig. 11.5).

The uppermost nerve roots pass horizontally from the spinal cord to reach the intervertebral foramina. Lower down they have to pass with increasing obliquity, as the spinal cord is much shorter than the vertebral column. Below the termination of the spinal cord at the level of 1st lumbar vertebra, the obliquity becomes more marked.

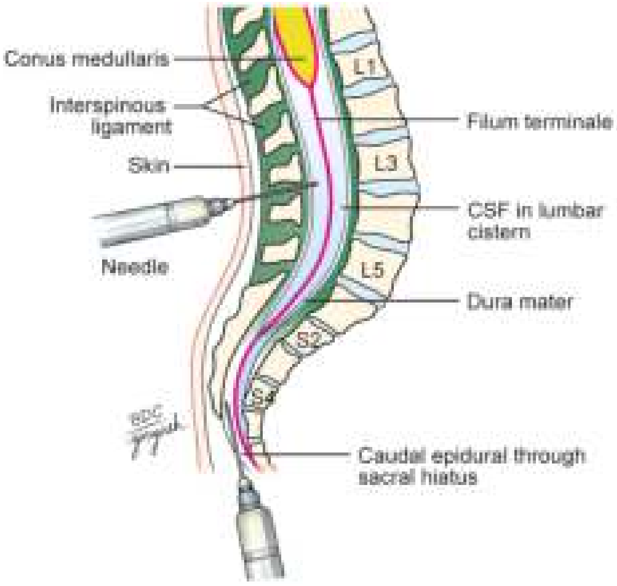

Conus medullaris
Interspinous ligament
Skin
Needle
L1
L3
L5
S2
S4
Filum terminale
CSF in lumbar cistern
Dura mater
Caudal epidural through sacral hiatus

Fig. 11.3: Lumbar puncture in an adult

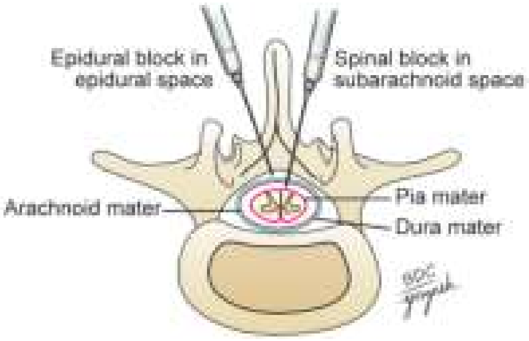

Epidural block in epidural space
Spinal block in subarachnoid space
Arachnoid mater
Pia mater
Dura mater

Fig. 11.4: Lumbar epidural anaesthesia and spinal block

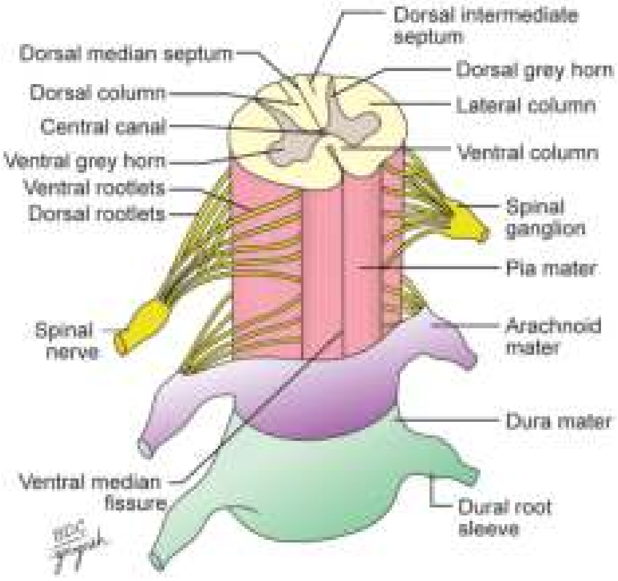

Dorsal intermediate septum
Dorsal median septum
Dorsal grey horn
Dorsal column
Lateral column
Central canal
Ventral grey horn
Ventral column
Ventral rootlets
Dorsal rootlets
Spinal ganglion
Pia mater
Spinal nerve
Arachnoid mater
Dura mater
Ventral median fissure
Dural root sleeve

Fig. 11.5: Formation of spinal nerve

Below the lower end of the spinal cord, the roots form a bundle known as the ***cauda equina*** because of its resemblance to the tail of a horse.

The roots of spinal nerves are surrounded by sheaths derived from the meninges. The ***pial and arachnoid sheaths*** extend up to the dura mater. The ***dural sheath*** encloses the terminal parts of the roots, continues over the nerve trunk, and is lost by merging with the epineurium of the nerve.

An intervertebral foramen contains:

a. The ends of the nerve roots
b. The dorsal root ganglion
c. The nerve trunk
d. The beginning of the dorsal and ventral rami
e. A spinal artery
f. An intervertebral vein.

CLINICAL ANATOMY

- ***Compression of the spinal cord*** by a tumour gives rise to paraplegia or quadriplegia, depending on the level of compression.
- Compression of roots of spinal nerves may be caused by prolapse of an intervertebral disc, by osteophytes (formed in osteoarthritis), by a cervical rib, or by an extramedullary tumour. Such compression results in shooting pain along the distribution of the nerve.
- ***Spinal tumours*** may arise from dura mater—meningioma, glial cells—glioma, nerve roots—neurofibroma, ependyma–ependymoma, and other tissues. Apart from compression of the spinal cord, the tumour causes obstruction of the subarachnoid space so that pressure of CSF is low below the level of lesion (***Froin's syndrome***). There is yellowish discolouration of CSF below the level of obstruction. CSF reveals high level of protein but the cell content is normal. ***Queckenstedt's test*** does not show a sudden rise and a sudden fall of CSF pressure by coughing or by brief pressure over the jugular veins. Spinal block can be confirmed either by myelography, CT scan or MRI scan.
- Compression of the cauda equina gives rise to flaccid paraplegia, saddle anaesthesia and sphincter disturbances. This is called the ***cauda equina syndrome***.

VERTEBRAL SYSTEM OF VEINS

The vertebral venous plexus assumes importance in cases of (Fig. 11.6):

1. Carcinoma of the prostate causing secondaries in the vertebral column and the skull.
2. Chronic empyema (collection of pus in the pleural cavity) causing brain abscess by septic emboli.

Anatomy of the Vertebral Venous Plexus/Batson Venous Plexus

The vertebral venous system is made up of a valveless, complicated network of veins with a longitudinal pattern. It runs parallel to and anastomoses with the superior and inferior venae cavae. This network has three intercommunicating subdivisions.

1. ***Epidural plexus:*** Lies in the vertebral canal outside the dura mater. The plexus consists of a postcentral and a prelaminar portion. Each portion is drained by two vessels. The plexus drains the structures in the vertebral canal, and is itself drained at regular intervals by segmental veins—vertebral, posterior intercostal, lumbar and lateral sacral.
2. ***Plexus within the vertebral bodies:*** It drains backwards into the epidural plexus, and anterolaterally into the external vertebral plexus.
3. ***External vertebral venous plexus:*** It consists of anterior vessels lying in front of the vertebral bodies, and the posterior vessels on the back of the vertebral arches and on adjacent muscles. It is drained by segmental veins.

The suboccipital plexus of veins is a part of the external plexus. It lies in the suboccipital triangle. It receives the occipital veins of the scalp is connected with the transverse sinus by emissary veins and drains into the subclavian veins.

Communications and Implications

Valveless vertebral system of veins communicates:

1. Above with the intracranial venous sinuses.
2. Below with the pelvic veins, the portal vein, and the caval system of veins.

The veins are *valveless* and the blood can flow in them in either direction. An increase in intrathoracic or intra-abdominal pressure, brought about by coughing and straining, may cause blood to flow in the plexus away from the heart, either upwards or downwards. Such periodic changes in venous pressure are clinically important because they make possible the spread of tumours or infections. For example, cells from pelvic, abdominal, thoracic and breast tumours may enter the venous system, and may ultimately lodge in the vertebrae, the spinal cord, the skull, or the brain.

The common primary sites of tumours causing secondaries in vertebrae are the breast and the prostate.

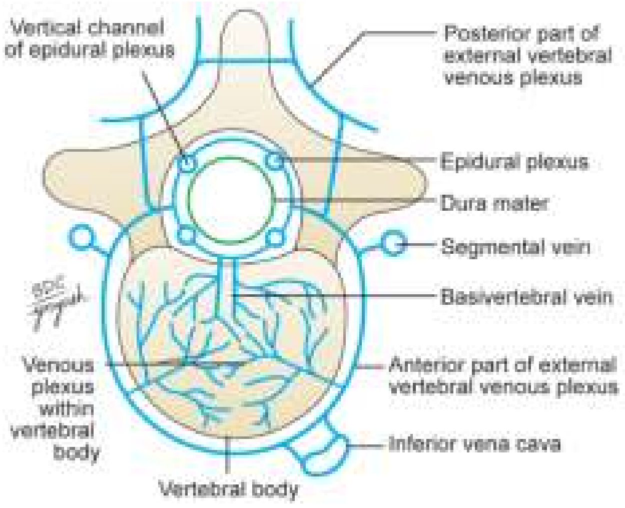

Vertical channel of epidural plexus
Posterior part of external vertebral venous plexus
Epidural plexus
Dura mater
Segmental vein
Basivertebral vein
Venous plexus within vertebral body
Anterior part of external vertebral venous plexus
Inferior vena cava
Vertebral body

Fig. 11.6: The vertebral system of veins

Facts to Remember

- Spinal cord in adult ends at lower border of lumbar one vertebra.
- Spinal dura mater and arachnoid mater extend till second sacral vertebra.
- Spinal pia mater comprises an outer epi-pia and an inner pia-intima.
- Ligamenta denticulata of pia mater are two vertical ridges with 21 tooth-like processes which suspend the spinal cord in the subarachnoid space.
- The lowest or 21st process lies between T12 and L1 spinal nerves.
- Through the vertebral venous plexus, secondaries of prostate or breast can reach up to the cranial cavity.

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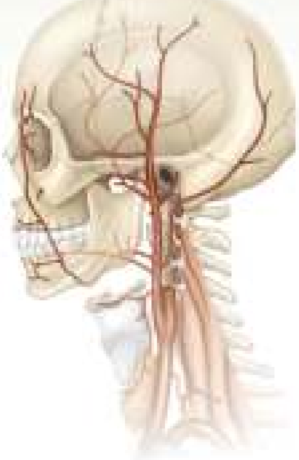
1. Viva voce questions
2. Nomenclature of spinal nerves

Chapter

12



Cranial Cavity

Cranial cavity contains the brain, meninges, venous sinuses, all cranial nerves, four petrosal nerves, parts of internal carotid artery and a part of the vertebral artery besides the special senses. The anterior branch of middle meningeal artery lies at the pterion and is prone to rupture resulting in extradural haemorrhage.

The convex upper wall of the cranial cavity is called the ***vault***. It is uniform and smooth.

The ***base of the cranial cavity*** is uneven and presents three cranial fossae (anterior, middle and posterior) lodging the uneven base of the brain.

CONTENTS OF CRANIAL CAVITY

The cranial cavity contains:

1. Brain
2. Meninges
   - Outer dura mater
   - Middle arachnoid mater
   - Inner pia mater
3. Hypophysis cerebri
4. Intracranial parts of cranial nerves
5. Dural venous sinuses including cavernous sinus
6. *Arteries*: Internal carotid arteries, 4th part of vertebral arteries, circle of Willis, and middle meningeal arteries.

DISSECTION

Detach the epicranial aponeurosis, if not already done, laterally till the inferior temporal line. In the region of the temple, detach the temporalis muscle with its overlying fascia and reflect these downwards over the pinna.

Removal of skull cap or calvaria

Draw a horizontal line across the skull 1 cm above the orbital margins and 1 cm above the inion. Saw through the skull. Be careful in the temporal region as skull is rather thin there. Separate the inner table of skull from the fused endosteum and dura mater.

Removal of the brain

To remove the brain and its enveloping meninges, the structures leaving or entering the brain through various foramina of the skull have to be carefully detached/incised. Start from the anterior aspect by detaching falx cerebri from the crista galli.

Put 2–3 blocks under the shoulders so that head falls backwards. This will expose the olfactory bulb, which may be lifted from the underlying anterior cranial fossa. Identify optic nerve, internal carotid artery, infundibulum passing towards hypophysis cerebri. Divide all three structures. Cut through the oculomotor and trochlear nerves in relation to free margin of tentorium cerebelli. Divide the attachment of tentorium from the petrous temporal bone.

Identify and divide trigeminal, abducent, facial, and vestibulocochlear nerves. Then cut glossopharyngeal, vagus, accessory and hypoglossal nerves. All these nerves have to be cut first on one side and then on the other side. Lastly identify the two vertebral arteries entering the skull through foramen magnum on each side of the spinal medulla. With a sharp knife, cut through these structures. Thus, the whole brain with the meninges can be gently removed from the skull. Preserve it in 5% formaldehyde.

Cut through the dura mater on the ventral aspect of brain till the inferolateral borders along the superciliary margin. Pull upwards the fold of dura mater present between the adjacent medial surfaces of cerebral hemispheres. This will be possible till the occipital lobe of brain. Pull backwards a similar but much smaller fold between two lobes of cerebellum, i.e. falx cerebelli.

Separating the cerebrum from the cerebellum is a double fold of dura mater called tentorium cerebelli. Pull it out in a horizontal plane by giving incision along the petrous temporal bone.

Learn about the folds of dura mater, i.e. falx cerebri, tentorium cerebelli, falx cerebelli, diaphragma sellae including trigeminal cave from the specimen with the help of base of skull. Make a paper model of these dural folds for recapitulation.

Competency:
AN30.3 Describe and identify dural folds and dural venous sinuses.

CEREBRAL DURA MATER

The dura mater is the outermost, thickest and toughest membrane covering the brain (*dura* = hard) (*mater* = mother) (Figs 12.1a to c).

LAYERS OF DURA MATER

There are **two layers** of dura:

1. Outer or ***endosteal layer*** which serves as an internal periosteum or endosteum or endocranium for the skull bones.
2. Inner or ***meningeal layer*** which surrounds the brain. The meningeal layer is continuous with the spinal dura mater.

The two layers are fused to each other at all places, except where the cranial venous sinuses are enclosed between them.

Endosteal Layer or Endocranium

1. The endocranium is continuous:
   a. With the periosteum lining the outside of the skull or pericranium through the sutures and foramina.
   b. With the periosteal lining of the orbit through the superior orbital fissure.
2. It provides ***sheaths*** for the cranial nerves, the sheaths fuse with the epineurium outside the skull.
3. Its outer surface is adherent to the inner surface of the cranial bones by a number of fine fibrous and vascular processes. The adhesion is most marked at the sutures, on the base of the skull and around the foramen magnum.

Note: Over the optic nerve, the dura forms a sheath which becomes continuous with the sclera.

Meningeal Layer

At places, the meningeal layer of dura mater is folded on itself to form partitions which divide the cranial cavity into compartments which lodge different parts of the brain. The folds are (Fig. 12.1b):

1. Falx cerebri
2. Tentorium cerebelli
3. Falx cerebelli
4. Diaphragma sellae.

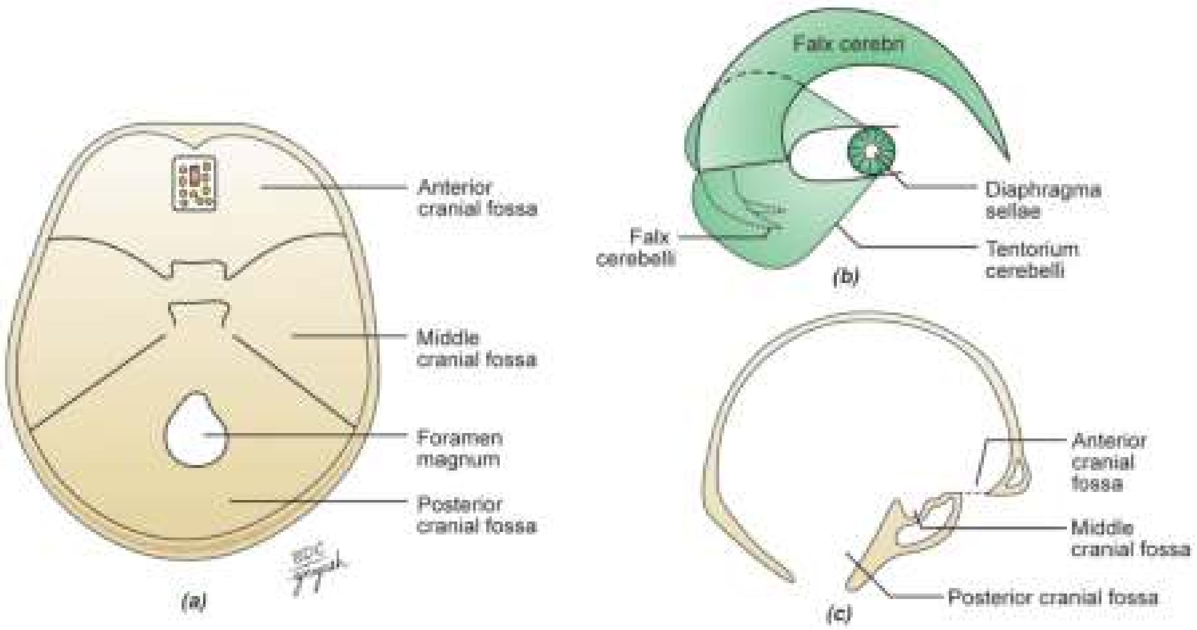
Blood Supply

The outer layer is richly vascular. The inner meningeal layer is more fibrous and requires little blood supply.

1. The vault or supratentorial space is supplied by the middle meningeal artery.
2. The anterior cranial fossa and the dural lining is supplied by meningeal branches of the anterior ethmoidal, posterior ethmoidal and ophthalmic arteries.
3. The middle cranial fossa is supplied by the middle meningeal, accessory meningeal, and internal carotid arteries; and by meningeal branches of the ascending pharyngeal artery.
4. The posterior cranial fossa is supplied by meningeal branches of the vertebral, occipital and ascending pharyngeal arteries.

Nerve Supply

1. The dura of the *vault* has only a few sensory nerves which are derived mostly from the ophthalmic division of the trigeminal nerve.



Figs 12.1a to c: The cranial cavity: (a) Three cranial fossae, (b) folds of meningeal layer of dura mater, and (c) sagittal section

2. The dura of the floor has a rich nerve supply and is quite sensitive to pain (Figs 12.1a and 12.1c).
   a. *Anterior cranial fossa* is supplied mostly by the anterior ethmoidal nerve and partly by the maxillary nerve.
   b. *Middle cranial fossa* is supplied by the maxillary nerve in its anterior half, and by branches of the mandibular nerve and from the trigeminal ganglion in its posterior half.
   c. *Posterior cranial fossa* is supplied chiefly by recurrent branches from first, second and third cervical spinal nerves and partly by meningeal branches of the ninth and tenth cranial nerves.

FOLDS OF DURA MATER

Falx Cerebri

The falx cerebri is a large sickle-shaped fold of dura mater occupying the median longitudinal fissure between the two cerebral hemispheres (Figs 12.2a to c, Flowchart 12.1).

Parts

Ends: It has two ends:

1. *Anterior end* is narrow, and is attached to the crista galli.
2. *Posterior end* is broad, and is attached along the median plane to the upper surface of the tentorium cerebelli.

Margins: The falx cerebri has two margins:

1. *Upper margin* is convex and is attached to the lips of the sagittal sulcus.
2. *Lower margin* is concave and free.

Surfaces: The falx cerebri has *right* and *left surfaces* each of which is related to the medial surface of the corresponding cerebral hemisphere.

Related Venous Sinuses

Three important venous sinuses are present in relation to this fold.

1. *Superior sagittal sinus* lies along the upper margin.
2. *Inferior sagittal* sinus along the lower margin.
3. *Straight sinus* along the line of attachment of the falx to the tentorium cerebelli (Figs 12.2a to c).

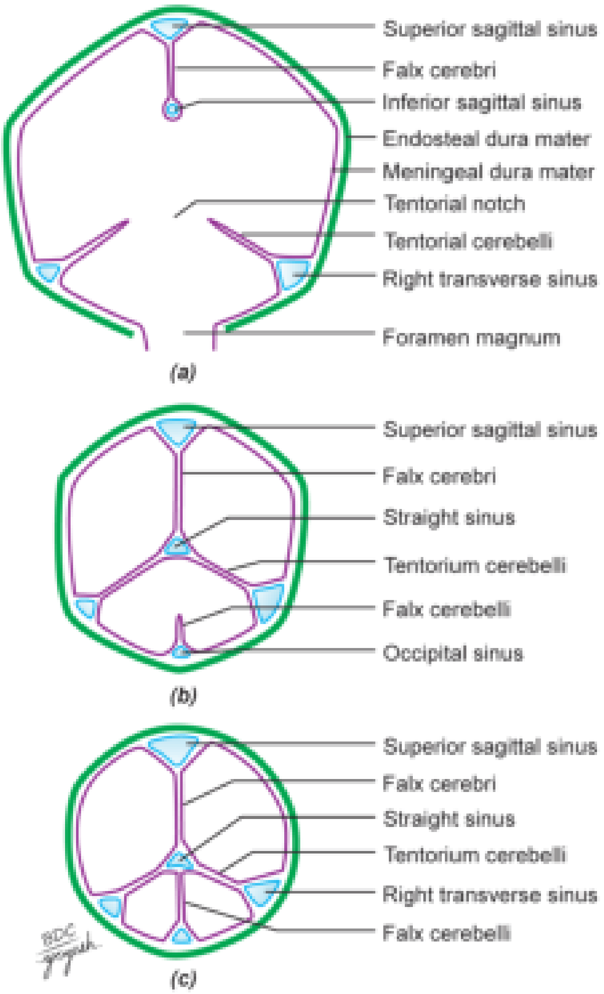
Tentorium Cerebelli

The tentorium cerebelli is a tent-shaped fold of dura mater, forming the roof of the posterior cranial fossa (Figs 12.3 and 12.4, Flowchart 12.2). It separates the cerebellum from the occipital lobes of the cerebrum, and broadly divides the cranial cavity into supratentorial and infratentorial compartments. The infratentorial compartment is the posterior cranial fossa containing the hindbrain and the lower part of the midbrain.

Parts

Margins: The tentorium cerebelli has a free margin and an attached margin.

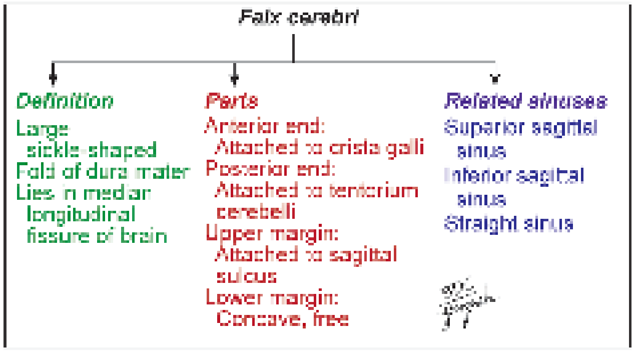
1. *Anterior free margin* is U-shaped and free. The ends of the 'U' are attached anteriorly to the anterior clinoid processes. This margin bounds the ***tentorial notch*** which is occupied by the midbrain and the anterior part of the superior vermis.



Superior sagittal sinus
Falx cerebri
Inferior sagittal sinus
Endosteal dura mater
Meningeal dura mater
Tentorial notch
Tentorial cerebelli
Right transverse sinus
Foramen magnum
(a)
Superior sagittal sinus
Falx cerebri
Straight sinus
Tentorium cerebelli
Falx cerebelli
Occipital sinus
(b)
Superior sagittal sinus
Falx cerebri
Straight sinus
Tentorium cerebelli
Right transverse sinus
Falx cerebelli
(c)

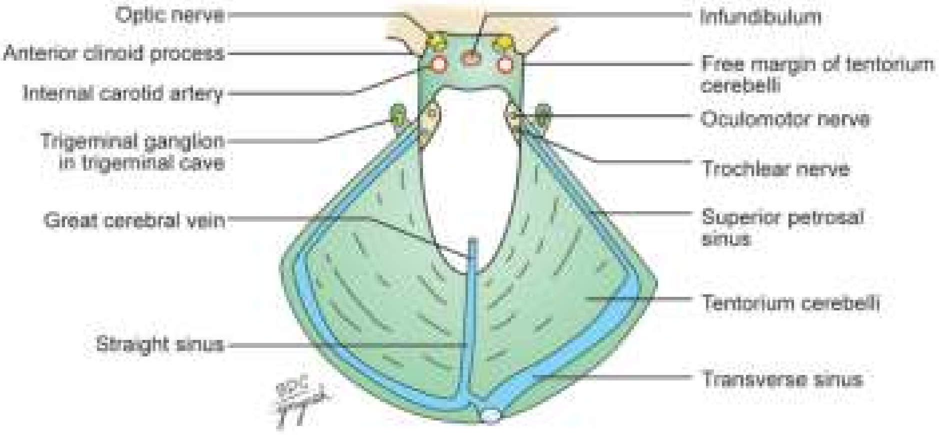
Figs 12.2a to c: Coronal sections through the posterior cranial fossa showing folds of dura mater and the venous sinuses enclosed in them: (a) Section through the tentorial notch (anterior part of the fossa), (b) section through the middle part of the fossa, and (c) section through the posterior most part

Flowchart 12.1: Falx cerebri



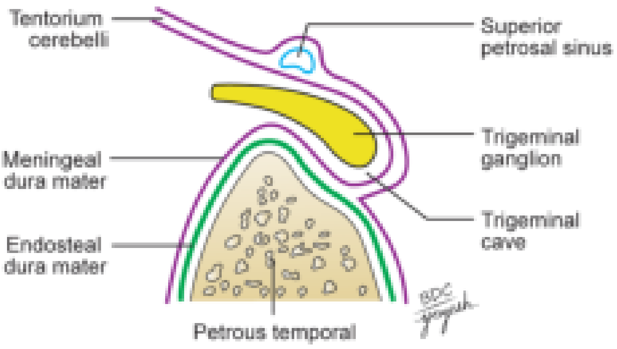
Falx cerebri
Definition
Large sickle-shaped
Fold of dura mater
Lies in median longitudinal fissure of brain
Parts
Anterior end: Attached to crista galli
Posterior end: Attached to tentorium cerebelli
Upper margin: Attached to sagittal sulcus
Lower margin: Concave, free
Related sinuses
Superior sagittal sinus
Inferior sagittal sinus
Straight sinus

2. *Outer or attached margin* is convex. Posterolaterally, it is attached to the lips of the transverse sulci on the occipital bone, and on the posteroinferior angle of the parietal bone. Anterolaterally, it is attached to the superior border of the petrous temporal bone and to



Optic nerve
Anterior clinoid process
Internal carotid artery
Trigeminal ganglion in trigeminal cave
Great cerebral vein
Straight sinus
Infundibulum
Free margin of tentorium cerebelli
Oculomotor nerve
Trochlear nerve
Superior petrosal sinus
Tentorium cerebelli
Transverse sinus

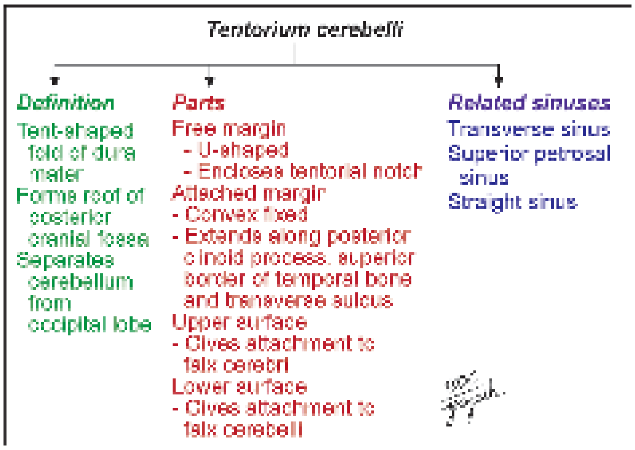
Fig. 12.3: Tentorium cerebelli and diaphragma sellae seen from above



Tentorium cerebelli
Superior petrosal sinus
Meningeal dura mater
Trigeminal ganglion
Trigeminal cave
Endosteal dura mater
Petrous temporal

Fig. 12.4: Parasagittal section through the petrous temporal bone and meninges to show the formation of the trigeminal cave

Flowchart 12.2: Tentorium cerebelli



Tentorium cerebelli
Definition
Tent-shaped fold of dura mater
Forms roof of posterior cranial fossa
Separates cerebellum from occipital lobe
Parts
Free margin
- U-shaped
- Encloses tentorial notch
Attached margin
- Convex fixed
- Extends along posterior clinoid process, superior border of temporal bone and transverse sulcus
Upper surface
- Gives attachment to falx cerebri
Lower surface
- Gives attachment to falx cerebelli
Related sinuses
Transverse sinus
Superior petrosal sinus
Straight sinus

the posterior clinoid processes. Along the attached margin, there are the transverse and superior petrosal venous sinuses.

Surfaces: The tentorium cerebelli has two surfaces—superior and inferior.

1. *Superior surface* is convex and slopes to either side from the median plane. The falx cerebri is attached to this surface in the midline; the straight sinus lies along the line of this attachment. The superior surface is related to the occipital lobes of the cerebrum.
2. *Inferior surface* is concave and fits the convex superior surface of the cerebellum. The falx cerebelli is attached to its posterior part (Fig. 12.2c).

Note:
The ***trigeminal*** **or *Meckel's cave*** is a recess of dura mater present in relation to the attached margin of the tentorium. It is formed by evagination of the inferior layer of the tentorium over the trigeminal impression on the petrous temporal bone. It contains the trigeminal ganglion (Fig. 12.4).

The free and attached margins of the tentorium cerebelli cross each other near the apex of the petrous temporal bone. Anterior to the point of crossing, there is a triangular area which forms the posterior part of the roof of cavernous sinus, and is pierced by the 3rd and 4th cranial nerves.

Falx Cerebelli

The falx cerebelli is a small sickle-shaped fold of dura mater projecting forwards into the posterior cerebellar notch (Fig. 12.2c).

Parts

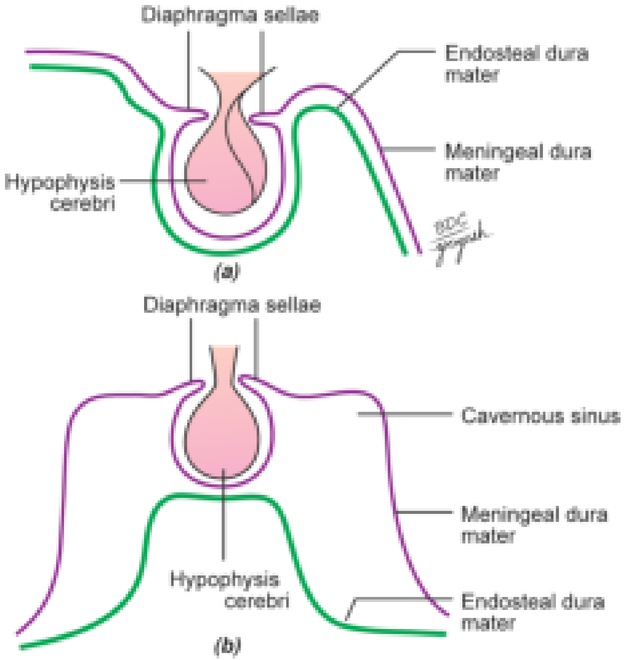
1. *Base* of the sickle is attached to the posterior part of the inferior surface of the tentorium cerebelli in the median plane.
2. *Apex* of the sickle is frequently divided into two parts which are lost on the sides of the foramen magnum.
3. *Posterior margin* is convex and is attached to the internal occipital crest. It encloses the occipital sinus.
4. *Anterior margin* is concave and free.

Diaphragma Sellae

The diaphragma sellae is a small circular, horizontal fold of dura mater forming the roof of the hypophyseal fossa (Figs 12.5a and b). The diaphragma has a ***central aperture*** through which the stalk of the hypophysis cerebri passes.

Attachments

1. *Anteriorly* – to the tuberculum sellae
2. *Posteriorly* – to the dorsum sellae.
3. *On each side* – continuous with the dura mater of the middle cranial fossa.


Diaphragma sellae
Endosteal dura mater
Meningeal dura mater
Hypophysis cerebri
(a)
Diaphragma sellae
Cavernous sinus
Meningeal dura mater
Hypophysis cerebri
Endosteal dura mater
(b)

Figs 12.5a and b: Diaphragma sellae as seen in: (a) Sagittal section and (b) coronal section

Competency:
AN30.4 Describe clinical importance of dural venous sinuses.

CLINICAL ANATOMY

Pain-sensitive intracranial structures: They are:

a. The large cranial venous sinuses and their tributaries from the surface of the brain
b. Dural arteries
c. The dural floor of the anterior and posterior cranial fossae
d. Arteries at the base of the brain.

Headache: It may be caused by:

a. Dilatation of intracranial arteries
b. Dilatation of extracranial arteries
c. Traction or distension of intracranial pain sensitive structures
d. Infection and inflammation of intracranial and extra-cranial structures supplied by the sensory, cranial and cervical nerves.

Extradural and subdural haemorrhages: Their differences are listed in Table 12.1.

VENOUS SINUSES OF DURA MATER

Definition: The dural venous sinuses are the venous spaces or channels present in the dura mater. These are lined by *endothelium*.

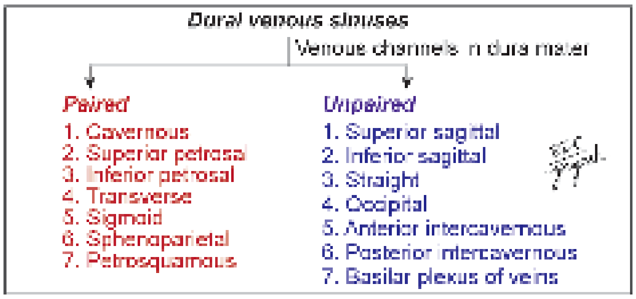
Features of Dural Venous (Flowchart 12.3)

1. The dural venous sinuses are formed by two ways:
   a. By separation of two layers of dura mater
   b. By folding of meningeal layer on itself.

TABLE 12.1: Differences between extradural and subdural haemorrhages

Feature	*Extradural (epidural) haemorrhage*	*Subdural haemorrhage*
Location	Between the skull and endosteal layer of dura mater	Between the dura mater and arachnoid mater
Involved vessels	Arteries (middle meningeal artery)	Veins
Symptoms	Rapid onset of symptoms (sudden onset of paralysis)	Gradual increasing symptoms
Blood in CSF	Absent	Present
CT scan appearance of hematoma	Biconvex lens	Crescent-shaped

Flowchart 12.3: Dural venous sinuses


Dural venous sinuses
Venous channels in dura mater
Paired
1. Cavernous
2. Superior petrosal
3. Inferior petrosal
4. Transverse
5. Sigmoid
6. Sphenoparietal
7. Petrosquamous
Unpaired
1. Superior sagittal
2. Inferior sagittal
3. Straight
4. Occipital
5. Anterior intercavernous
6. Posterior intercavernous
7. Basilar plexus of veins

2. Lined by endothelium only
3. Muscle coat is absent in their walls
4. Devoid of valves in their lumen
5. Receive blood and CSF both
6. Communicates with veins outside the skull through emissary veins. It helps to maintain the constant blood pressure in the sinuses.

Classification of Dural Venous Sinuses

There are 23 venous sinuses, of which 8 are paired and 7 are unpaired.

Paired venous sinuses

There is one sinus each on right and left side.

1. Cavernous sinus
2. Superior petrosal sinus
3. Inferior petrosal sinus
4. Transverse sinus
5. Sigmoid sinus
6. Sphenoparietal sinus
7. Petrosquamous sinus
8. Middle meningeal sinus/veins

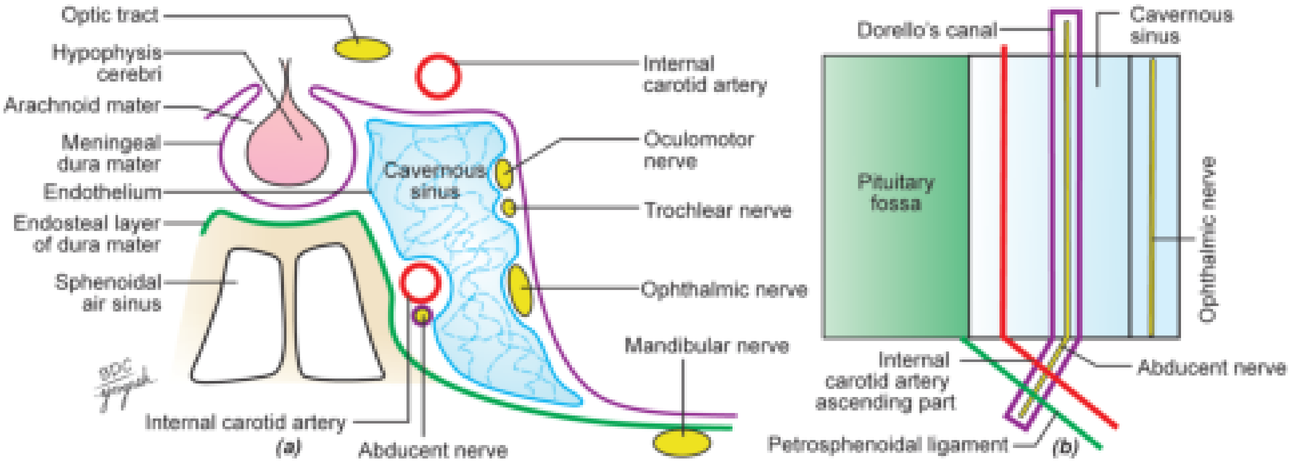
Unpaired venous sinuses

These are median in position.

1. Superior sagittal sinus
2. Inferior sagittal sinus
3. Straight sinus
4. Occipital sinus
5. Anterior intercavernous sinus
6. Posterior intercavernous sinus
7. Basilar plexus of veins

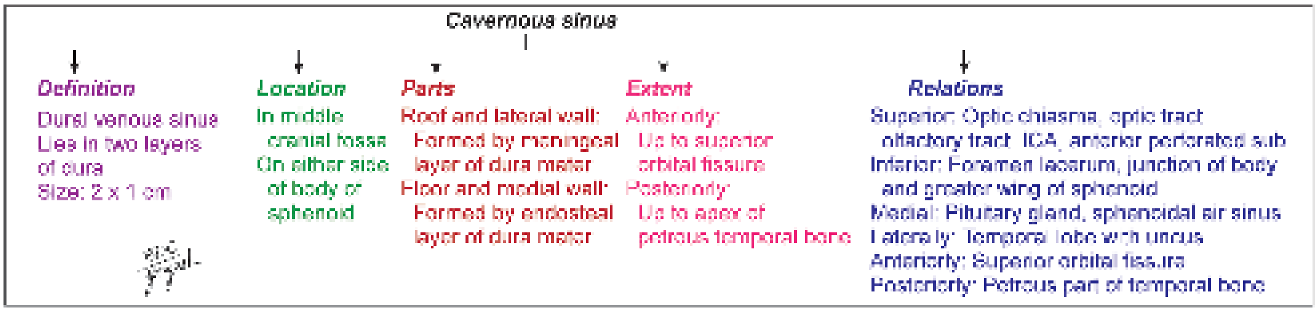
CAVERNOUS SINUS

Cavernous sinus is a large dural venous sinus that lies between the two layers of the dura mater (Figs 12.6a and b, Flowchart 12.4).


Optic tract
Hypophysis cerebri
Arachnoid mater
Meningeal dura mater
Endothelium
Endosteal layer of dura mater
Sphenoidal air sinus
Internal carotid artery
(a)
Abducent nerve
Cavernous sinus
Internal carotid artery
Oculomotor nerve
Trochlear nerve
Ophthalmic nerve
Mandibular nerve
Dorello's canal
Cavernous sinus
Pituitary fossa
Ophthalmic nerve
Internal carotid artery ascending part
Abducent nerve
Petrosphenoidal ligament
(b)

Figs 12.6a and b: (a) Coronal section through the middle cranial fossa showing the relations of the cavernous sinus and (b) Dorellos's canal (*Courtesy*: Prof. SN Kazi)

Flowchart 12.4: Cavernous sinuses: Location, parts, extent and relations


Cavernous sinus
Definition
Dural venous sinus
Lies in two layers of dura
Size: 2 x 1 cm
Location
In middle cranial fossa
On either side of body of sphenoid
Parts
Roof and lateral wall: Formed by meningeal layer of dura mater
Floor and medial wall: Formed by endosteal layer of dura mater
Extent
Anteriorly: Up to superior orbital fissure
Posteriorly: Up to apex of petrous temporal bone
Relations
Superior: Optic chiasma, optic tract olfactory tract, ICA, anterior perforated sub
Inferior: Foramen lacerum, junction of body and greater wing of sphenoid
Medial: Pituitary gland, sphenoidal air sinus
Laterally: Temporal lobe with uncus
Anteriorly: Superior orbital fissure
Posteriorly: Petrous part of temporal bone

Size: It is about 2 cm long, and 1 cm wide.

Location: Each cavernous sinus lies in the middle cranial fossa, on either side of the body of sphenoid bone.

Parts (Structure)

The cavernous sinus lies between two layers of dura mater. Each cavernous sinus has a roof, floor, and two walls (medial and lateral).

1. Roof and lateral wall is formed by the meningeal layer of dura mater.
2. Floor and medial wall is formed by the endosteal layer of dura mater.

Note: The interior of the cavernous sinus is divided into a number of spaces or caverns by trabeculae. The trabeculae are much less conspicuous in the living than in the dead.

Extent

Each sinus extends.

Anteriorly: Up to the medial end of superior orbital fissure.

Posteriorly: Up to the apex petrous part of temporal bone.

Relations

Superior: Optic tract, optic chiasma, olfactory tract, internal carotid artery and anterior perforated substance.

Inferior: Foramen lacerum and the junction of the body and greater wing of the sphenoid bone.

Medial: Hypophysis cerebri and sphenoidal air sinus.

Lateral: Temporal lobe with uncus.

Anterior: Superior orbital fissure and the apex of the orbit.

Posterior: Apex of the petrous temporal and the crus cerebri of the midbrain.

Structures within the Lateral Wall of the Sinus (from above downwards) (Flowchart 12.5)

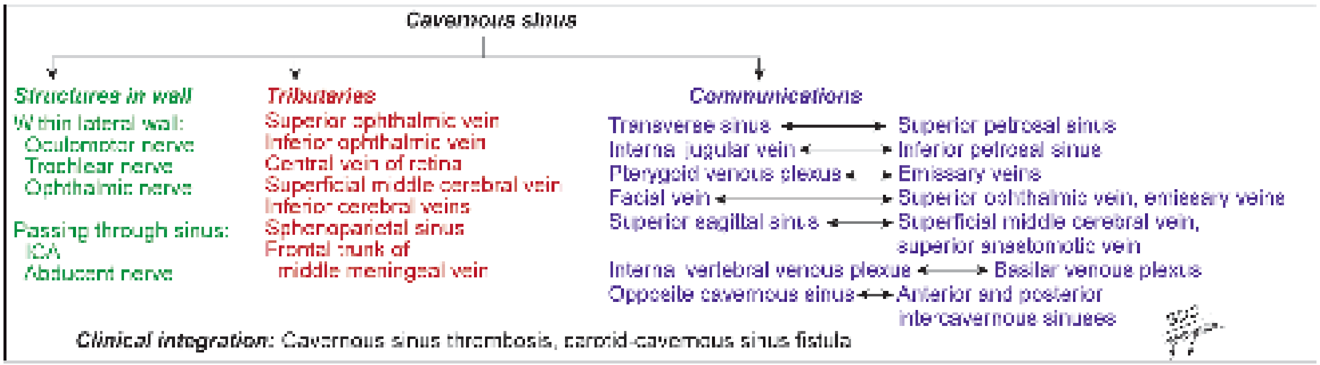
1. Oculomotor nerve
2. Trochlear nerve
3. Ophthalmic nerve
4. Maxillary nerve

Note:

1. *Oculomotor nerve*: In the anterior part of the sinus, it divides into superior and inferior divisions which leave the sinus by passing through the superior orbital fissure.
2. *Trochlear nerve:* In the anterior part of the sinus, it crosses superficial to the oculomotor nerve, and enters the orbit through the superior orbital fissure.
3. *Ophthalmic nerve:* In the anterior part of the sinus, it divides into the lacrimal, frontal and nasociliary nerves.
4. *Maxillary nerve:* It does not pass through cavernous sinus or its lateral wall. It courses beneath the dura mater of middle cranial fossa. It passes below the level of cavernous sinus by piercing cavum trigeminale (refer to Gray's Anatomy, 42nd edition).

The structures in the lateral wall and on the medial aspect of the sinus are separated from blood by the endothelial lining.

Flowchart 12.5: Cavernous sinus: Structures in wall, tributaries and communications


Cavernous sinus
Structures in wall
Within lateral wall:
Oculomotor nerve
Trochlear nerve
Ophthalmic nerve
Passing through sinus:
ICA
Abducent nerve
Tributaries
Superior ophthalmic vein
Inferior ophthalmic vein
Central vein of retina
Superficial middle cerebral vein
Inferior cerebral veins
Sphenoparietal sinus
Frontal trunk of middle meningeal vein
Communications
Transverse sinus ↔ Superior petrosal sinus
Internal jugular vein ↔ Inferior petrosal sinus
Pterygoid venous plexus ↔ Emissary veins
Facial vein ↔ Superior ophthalmic vein, emissary veins
Superior sagittal sinus ↔ Superficial middle cerebral vein, superior anastomotic vein
Internal vertebral venous plexus ↔ Basilar venous plexus
Opposite cavernous sinus ↔ Anterior and posterior intercavernous sinuses
Clinical integration: Cavernous sinus thrombosis, carotid-cavernous sinus fistula

Structures Passing through the Medial Aspect of the Sinus

1. *Internal carotid artery* with the venous and sympathetic plexus around it.
2. *Abducent nerve*.

Note: The abducent nerve enters the cavernous sinus by passing inferior to the petrosphenoidal ligament within a dural tunnel (***Dorello's canal***) (Fig. 12.6b) just posterior to the short ascending portion of the cavernous carotid artery, and then runs on the inferolateral side of the horizontal portion of the cavernous carotid artery, just medial to the ophthalmic nerve at the lateral wall of the sinus, known as the ***infratrochlear or Parkinson's triangle.*** It gives access to the horizontal portion of the cavernous carotid artery and the abducent nerve (Fig. 12.7).

Tributaries or Incoming Channels (Figs 12.8 and 12.9)

From the orbit

1. Superior ophthalmic vein.
2. Branch of the inferior ophthalmic vein or sometimes the vein itself.
3. Central vein of the retina may drain either into the superior ophthalmic vein or into the cavernous sinus.

From the brain

1. Superficial middle cerebral vein.
2. Inferior cerebral veins from the temporal lobe.

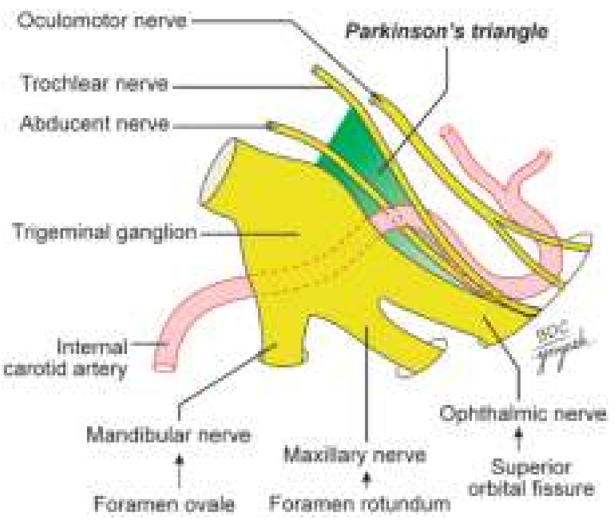

Oculomotor nerve
Parkinson's triangle
Trochlear nerve
Abducent nerve
Trigeminal ganglion
Internal carotid artery
Mandibular nerve
Foramen ovale
Maxillary nerve
Foramen rotundum
Ophthalmic nerve
Superior orbital fissure

Fig. 12.7: Infratrochlear or Parkinson's triangle

From the meninges

1. Sphenoparietal sinus.
2. Frontal trunk of the middle meningeal vein.
3. From the face—facial vein → deep facial vein → pterygoid plexus → emissary vein → cavernous sinus.

Draining Channels or Communications

The cavernous sinus drains (Figs 12.10 and 12.11):

1. Into the transverse sinus through the superior petrosal sinus.
2. Into the internal jugular vein through the inferior petrosal sinus and through a plexus around the internal carotid artery.
3. Into the pterygoid plexus of veins through the emissary veins passing through the foramen ovale, the foramen lacerum and the emissary sphenoidal foramen.
4. Into the facial vein through the superior ophthalmic vein.
5. The right and left cavernous sinuses communicate with each other through the anterior and posterior intercavernous sinuses and the basilar plexus of veins.

All these communications are valveless, and blood can flow through them in either direction.

Factors Helping Expulsion of Blood from the Sinus

1. Expansile pulsations of the internal carotid artery within the sinus
2. Gravity
3. Position of the head

CLINICAL ANATOMY

- ***Thrombosis of the cavernous sinus*** may be caused by sepsis in the dangerous area of the face, in nasal cavities, and paranasal air sinuses. This gives rise to the following symptoms:
  - a. ***Nervous symptoms:***
    - Severe pain in the eye and forehead in the area of distribution of ophthalmic nerve.
    - Involvement of the third, fourth and sixth cranial nerves resulting in paralysis of the muscles supplied.

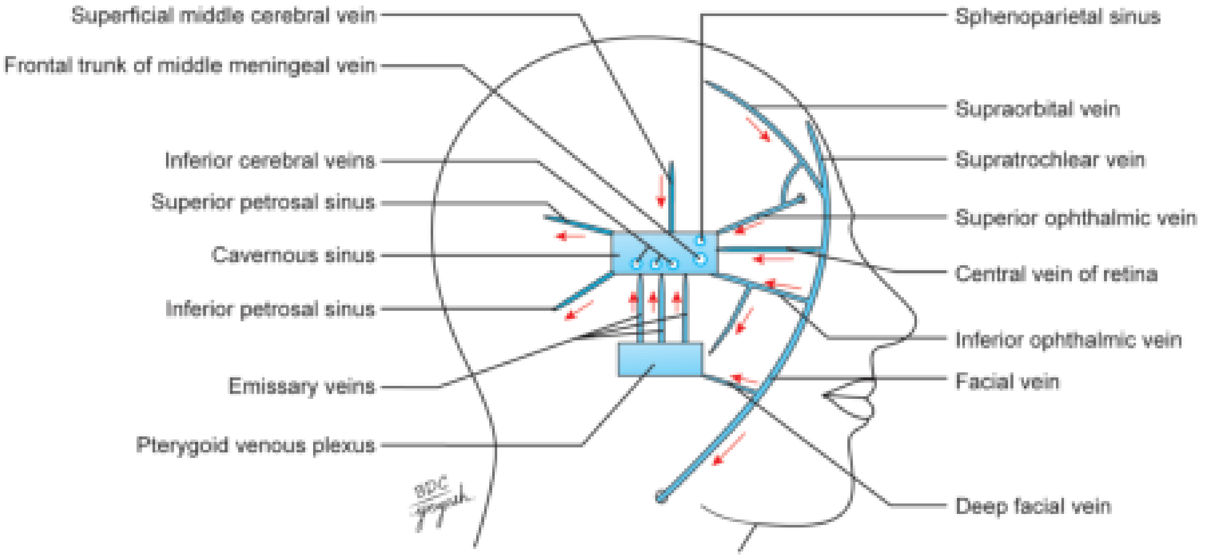

Superficial middle cerebral vein
Frontal trunk of middle meningeal vein
Inferior cerebral veins
Superior petrosal sinus
Cavernous sinus
Inferior petrosal sinus
Emissary veins
Pterygoid venous plexus
Sphenoparietal sinus
Supraorbital vein
Supratrochlear vein
Superior ophthalmic vein
Central vein of retina
Inferior ophthalmic vein
Facial vein
Deep facial vein

Fig. 12.8: Side view of the tributaries and communications of the cavernous sinus. Arrows show the direction of blood flow

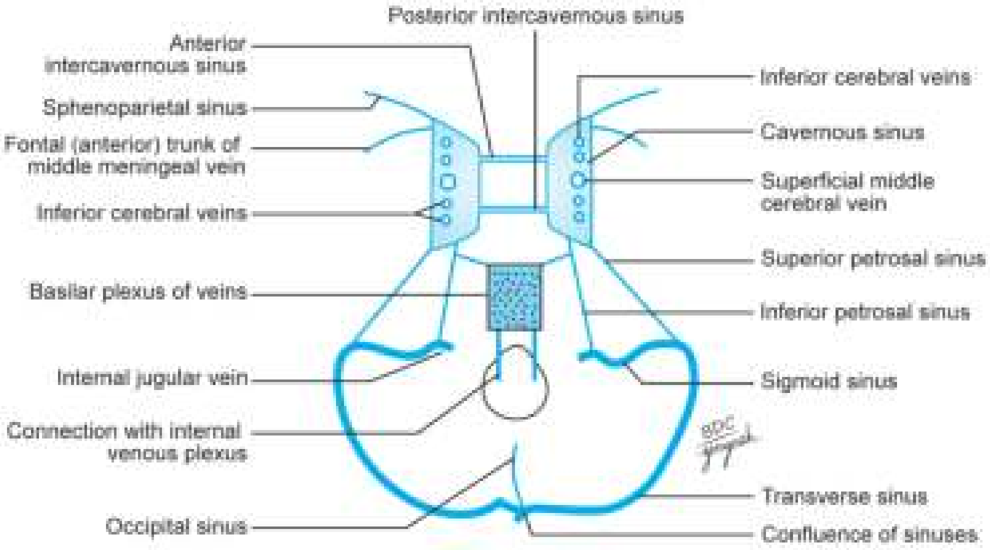

Posterior intercavernous sinus
Anterior intercavernous sinus
Sphenoparietal sinus
Fontal (anterior) trunk of middle meningeal vein
Inferior cerebral veins
Basilar plexus of veins
Internal jugular vein
Connection with internal venous plexus
Occipital sinus
Inferior cerebral veins
Cavernous sinus
Superficial middle cerebral vein
Superior petrosal sinus
Inferior petrosal sinus
Sigmoid sinus
Transverse sinus
Confluence of sinuses

Fig. 12.9: Superior view of the tributaries and communications of the cavernous sinus. Arrows show the direction of blood flow

b. ***Venous symptoms:*** Marked oedema of eyelids, cornea and root of the nose, with exophthalmos due to congestion of the orbital veins.

- A communication between the cavernous sinus and the internal carotid artery may be produced by head injury. When this happens the eyeball protrudes and pulsates with each heartbeat. It is called the ***pulsating exophthalmos***.

DISSECTION

Define the cavernous sinuses situated on each side of the body of the sphenoid bone. Cut through it between the anterior and posterior ends and locate its contents. Define its connections with the other venous sinuses and veins.

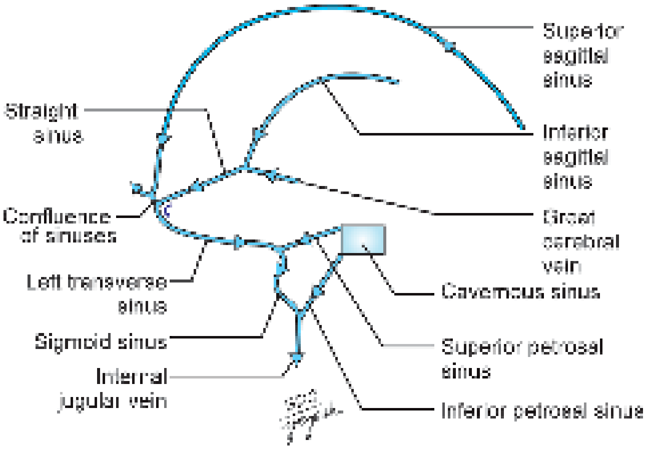

Superior sagittal sinus
Inferior sagittal sinus
Great cerebral vein
Cavernous sinus
Superior petrosal sinus
Inferior petrosal sinus
Straight sinus
Confluence of sinuses
Left transverse sinus
Sigmoid sinus
Internal jugular vein

Fig. 12.10: Scheme to show the lateral view of the intracranial venous sinuses. Arrowheads show the direction of blood flow

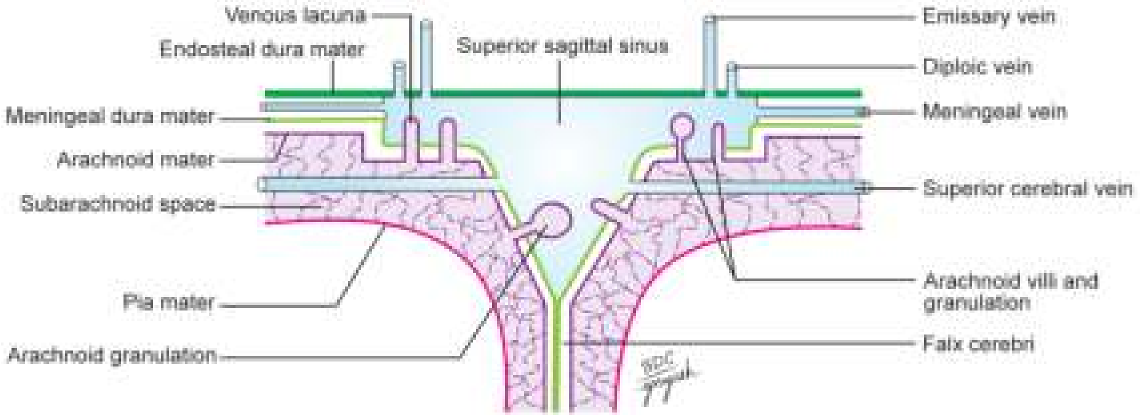


Fig. 12.11: Coronal section through superior sagittal sinus showing arrangement of the meninges, the arachnoid villi and granulations, and the various (emissary, diploic, meningeal and cerebral) veins in its relation

OTHER SINUSES

Superior Sagittal Sinus

The superior sagittal sinus occupies the upper convex, attached margin of the falx cerebri (Figs 12.10 and 12.11).

It begins anteriorly at the crista galli by the union of tiny meningeal veins. Here it communicates with the veins of the frontal sinus, and occasionally with the veins of the nose, through the foramen caecum. As the sinus runs upwards and backwards, it becomes progressively larger in size. It is triangular on cross-section. It ends near the internal occipital protuberance by turning to one side, usually the right, and becomes continuous with the right transverse sinus (Fig. 12.10). It generally communicates with the opposite sinus. The junction of all these sinuses is called the ***confluence of sinuses***.

The *interior* of the sinus shows:

1. Openings of the superior cerebral veins.
2. Openings of venous lacunae, usually three on each side.
3. Arachnoid villi and granulations projecting into the lacunae as well as into the sinus (Fig. 12.11).
4. Numerous fibrous bands crossing the inferior angle of the sinus.

Tributaries:

1. Superior cerebral veins which never open into the venous lacunae (Fig. 12.11).
2. Parietal emissary veins (Table 12.2).
3. Venous lacunae, usually three on each side which first, receive the diploic and meningeal veins, and then open into the sinus.
4. Occasionally, a vein from the nose opens into the sinus when the foramen caecum is patent.

Inferior Sagittal Sinus

The inferior sagittal sinus, a small channel, lies in the posterior two-thirds of the lower, concave free margin of the falx cerebri. It ends by joining the great cerebral vein to form the straight sinus (Fig. 12.10).

TABLE 12.2: Emissary veins: Valveless and communicate intracranial with extracranial veins

Sinus	*Connection*	*Veins*
Superior sagittal sinus	Parietal emissary vein Foramen caecum Middle meningeal vein	Veins of scalp, nasal veins Pterygoid veins
Transverse sinus	Petrosquamous	External jugular
Sigmoid sinus	Mastoid vein Hypoglossal vein Posterior condylar vein	Posterior auricular IJV Suboccipital vein
Cavernous sinus	Emissary veins Veins around ICA Ophthalmic vein Inferior petrosal	Pterygoid veins IJV Facial vein IJV

ICA: Internal carotid artery; IJV: Internal jugular vein

Straight Sinus

The straight sinus lies in the median plane within the junction of falx cerebri and the tentorium cerebelli. It is formed anteriorly by the union of the inferior sagittal sinus with the great cerebral vein, and ends at the internal occipital protuberance by continuing as the transverse sinus usually left (Fig. 12.10).

Transverse Sinuses

The transverse sinuses are large sinuses. The right sinus usually larger than the left, is situated in the posterior part of the attached margin of the tentorium cerebelli. The right transverse sinus is usually a continuation of the superior sagittal sinus, and the left sinus a continuation of the straight sinus. Each sinus extends from the internal occipital protuberance to the posteroinferior angle of the parietal bone at the base of mastoid process where it bends downwards and becomes the sigmoid sinus.

Tributaries:

1. Superior petrosal sinus
2. Inferior cerebral veins
3. Inferior cerebellar veins
4. Diploic (posterior temporal) vein
5. Inferior anastomotic vein.

Sigmoid Sinuses

Each sinus, right or left, is the direct continuation of the transverse sinus (Fig. 12.9). It is S-shaped, hence the name. It extends from the posteroinferior angle of the parietal bone to the posterior part of the jugular foramen where it becomes the superior bulb of the internal jugular vein. It grooves the mastoid part of the temporal bone, where *it is separated anteriorly from the mastoid antrum and mastoid air cells by only a thin plate of bone*.

Tributaries:

1. Mastoid and condylar emissary veins
2. Cerebellar veins
3. Internal auditory vein.

Occipital Sinus

The occipital sinus is small, and lies in the attached margin of the falx cerebelli. It begins near the foramen magnum and ends in the confluence of sinuses (Fig. 12.9).

Sphenoparietal Sinuses

The sphenoparietal sinuses, right and left, lie along the posterior free margin of the lesser wing of the sphenoid bone, and drain into the anterior part of the cavernous sinus. Each sinus may receive the frontal trunk of the middle meningeal vein (Fig. 12.10).

Superior Petrosal Sinuses

The superior petrosal sinuses lie in the anterior part of the attached margin of the tentorium cerebelli along the upper border of the petrous temporal bone. It drains the cavernous sinus into the transverse sinus (Fig. 12.9).

Inferior Petrosal Sinuses

The inferior petrosal sinuses, right and left, lie in the corresponding petro-occipital fissure, and drain the cavernous sinus into the superior bulb of the internal jugular vein.

Basilar Plexus of Veins

The basilar plexus of veins lies over the clivus of the skull. It connects the two inferior petrosal sinuses and communicates with the internal vertebral venous plexus.

Middle Meningeal Veins

The middle meningeal veins form two main trunks, one frontal or anterior and one parietal or posterior, which accompany the two branches of the middle meningeal artery.

1. The ***frontal trunk*** may end either in the pterygoid plexus through the foramen ovale, or in the sphenoparietal or cavernous sinus.
2. The ***parietal trunk*** usually ends in the pterygoid plexus through the foramen spinosum. The meningeal veins are nearer to the bone than the arteries, and are, therefore, more liable to injury in fractures of the skull.

Intercavernous Sinuses

The anterior and posterior intercavernous sinuses connect the cavernous sinuses. They pass through the diaphragma sellae, one in front and the other behind the infundibulum (Fig. 12.9).

CLINICAL ANATOMY

- ***Thrombosis of the superior sagittal sinus*** may be caused by spread of infection from the nose, scalp and diploe. This gives rise to:
  - A considerable rise in intracranial tension due to defective absorption of CSF.
  - Delirium and sometimes convulsions due to congestion of the superior cerebral veins.
  - Paraplegia of the upper motor neuron type due to bilateral involvement of the paracentral lobules of cerebrum where the lower limbs and perineum are represented.
- Spread of infection or thrombosis from the sigmoid and transverse sinuses to the superior sagittal sinus may cause impaired CSF drainage into the latter and may, therefore, lead to the development of hydrocephalus. Such a hydrocephalus associated with sinus thrombosis following ear infection is known as ***otitic hydrocephalus***.
- ***Thrombosis of the sigmoid sinus*** is always secondary to infection in the middle ear/otitis media, or in the mastoid process called mastoiditis.
- During operations on the mastoid process, one should be careful about the sigmoid sinus, so that it is not exposed.

HYPOPHYSIS CEREBRI (PITUITARY GLAND)

The hypophysis cerebri is a small endocrine gland situated in relation to the base of the brain. It is often called the ***master of the endocrine orchestra*** because it produces a number of hormones which control the secretions of many other endocrine glands of the body (Figs 12.12a and b).

Location

The gland lies in the hypophyseal fossa or ***sella turcica*** or pituitary fossa. The fossa is roofed by the diaphragma sellae. The stalk of the hypophysis cerebri pierces the diaphragma sellae and is attached above to the floor of the third ventricle.

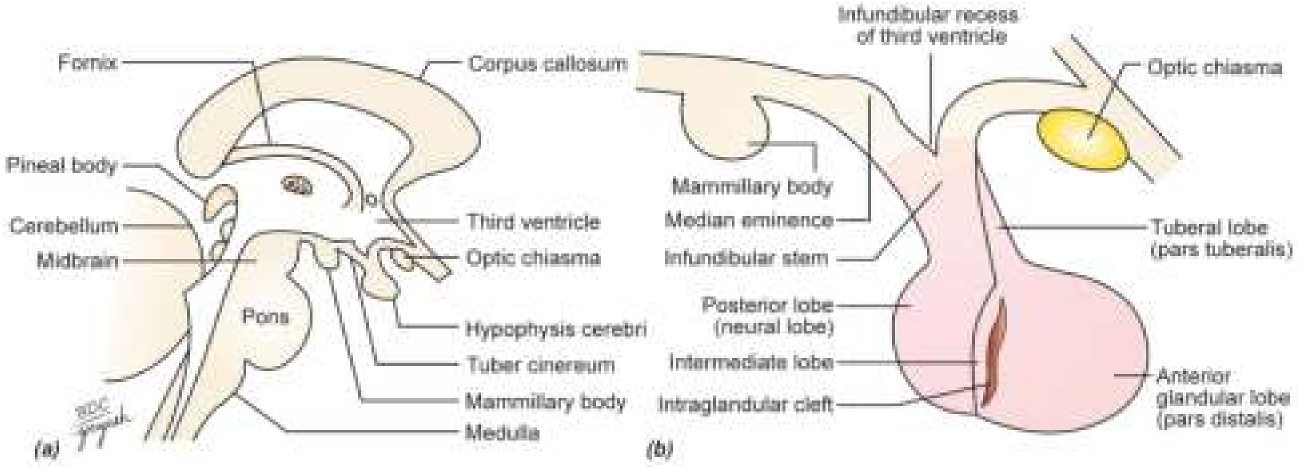
Measurements

The gland is oval in shape, and measures 8 mm anteroposteriorly and 12 mm transversely. It weighs about 500 mg.

Relations

Superior

1. Diaphragma sellae
2. Optic chiasma
3. Tubercinerium
4. Infundibular recess of the third ventricle


Fornix
Corpus callosum
Pineal body
Cerebellum
Midbrain
Third ventricle
Optic chiasma
Pons
Hypophysis cerebri
Tuber cinereum
Mammillary body
Medulla
(a)
Infundibular recess
of third ventricle
Optic chiasma
Mammillary body
Median eminence
Infundibular stem
Tuberal lobe
(pars tuberalis)
Posterior lobe
(neural lobe)
Intermediate lobe
Intraglandular cleft
Anterior
glandular lobe
(pars distalis)
(b)

Figs 12.12a and b: (a) Sagittal section of diencephalon and the brainstem showing structures at the base of brain including hypophysis cerebri, (b) parts of the hypophysis cerebri as seen in a sagittal section

Inferior

1. Irregular venous channels between the two layers of dura mater lining the floor of the hypophyseal fossa.
2. Hypophyseal fossa.
3. Sphenoidal air sinuses

Lateral

Cavernous sinus with its contents.

Competency:
AN43.4 Describe the development and developmental basis of congenital anomalies of face, palate, tongue, branchial apparatus, pituitary gland, thyroid gland and eye. Development of pituitary gland is given here. Development of other organs is given with their respective chapters.

Subdivisions/Parts and Development

The gland has two main parts: *Adenohypophysis* and *neurohypophysis* which differ from each other embryologically, morphologically and functionally (Figs 12.12a and b, Plate 12.1).

The adenohypophysis develops as an upward growth called the ***Rathke's pouch*** from the ectodermal roof of the stomodeum. The neurohypophysis develops as a downward growth from the floor of the diencephalon, and is connected to the hypothalamus by neural pathways.

The subdivisions of each part are given below:

Adenohypophysis

1. ***Anterior lobe*** **or** ***pars anterior, pars distalis, or pars glandularis:*** This is the largest part of the gland (Fig. 12.11).
2. ***Intermediate lobe*** **or** ***pars intermedia:*** This is in the form of a thin strip which is separated from the anterior lobe by an intraglandular cleft, a remnant of the lumen of Rathke's pouch.
3. ***Tuberal lobe*** **or** ***pars tuberalis:*** It is an upward extension of the anterior lobe that surrounds and forms part of the infundibulum.

Neurohypophysis

1. ***Posterior lobe*** **or** ***neural lobe, pars posterior:*** It is smaller than the anterior lobe and lies in the posterior concavity of the larger anterior lobe.
2. ***Infundibular stem***, which contains the neural connections of the posterior lobe with the hypothalamus.
3. ***Median eminence*** of the tuber cinerium which is continuous with the infundibular stem.

Arterial Supply

The hypophysis cerebri is supplied by the following branches of the internal carotid artery (Fig. 12.13).

1. One superior hypophyseal artery on each side.
2. One inferior hypophyseal artery on each side.

Venous Drainage

Short veins emerge on the surface of the gland and drain into neighbouring dural venous sinuses. The hormones pass out of the gland through the venous blood, and are carried to their target cells.

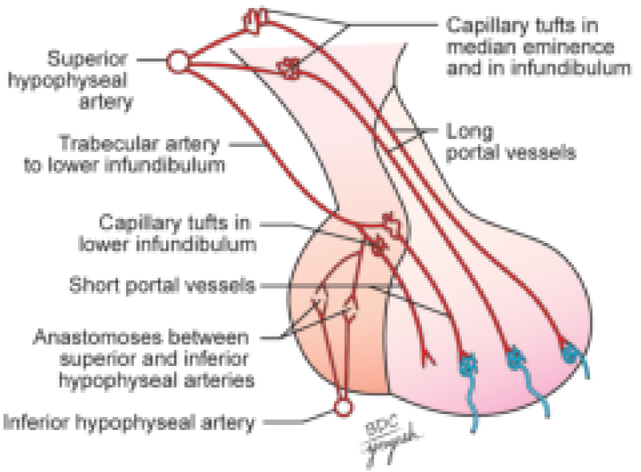
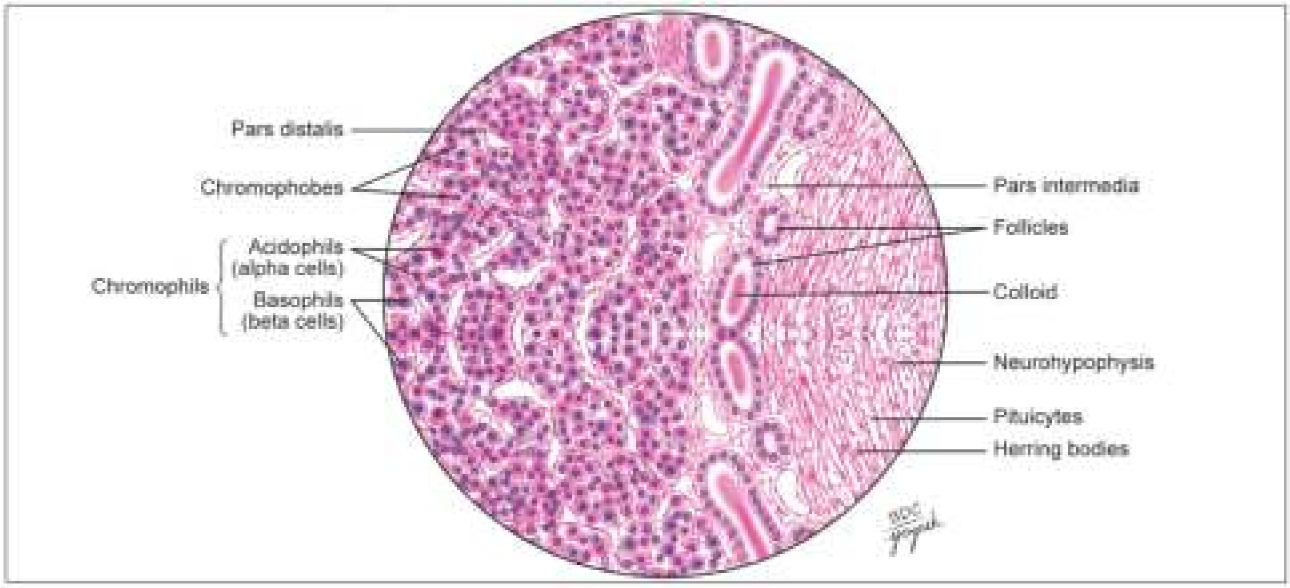

Superior
hypophyseal
artery
Capillary tufts in
median eminence
and in infundibulum
Trabecular artery
to lower infundibulum
Long
portal vessels
Capillary tufts in
lower infundibulum
Short portal vessels
Anastomoses between
superior and inferior
hypophyseal arteries
Inferior hypophyseal artery

Fig. 12.13: Arterial supply of the hypophysis cerebri. Note that the neurohypophysis is supplied by the superior and inferior hypophyseal arteries, and the adenohypophysis, exclusively by the portal vessels

Plate 12.1: Histology of hypophysis cerebri



Competency:
AN43.2 Identify, describe and draw the microanatomy of pituitary gland, thyroid, parathyroid gland, tongue, salivary glands, tonsil, epiglottis, cornea, retina. Histology of other organs is given with their respective chapters.

Histology of Pituitary Gland

Pituitary gland consists of (Plate 12.1)

- Adenohypophysis that have pars distalis, pars intermedia, and pars tuberalis
- Neurohypophysis

Adenohypophysis shows clumps or cords of cells separated by fenestrated capillaries. These cells consist of:

Acidophils: Having pink granules
- Somatotrophs (50%) secrete growth hormone
- Lactotropes (15–20%) secrete prolactin

Basophils: Having dark blue granules
- Corticotropes (15–20%) secrete ACTH
- Gonadotropes (10%) secrete LH and FSH
- Thyrotropes (5%) secrete TSH

Pars intermedia consists of a series of colloid-filled cysts/vesicles that secrete MSH.

Neurohypophysis consists of nonmyelinated axons and ***pituicytes***. Bodies of these neurons lie in supraoptic and paraventricular nuclei of hypothalamus. Neurohypophysis secretes vasopressin/ADH and oxytocin.

Hypothalamo-hypophyseal Portal System

1. Each ***superior hypophyseal artery*** supplies:
   a. Ventral part of the hypothalamus
   b. Upper part of the infundibulum
   c. Lower part of the infundibulum through a separate long descending branch, called the trabecular artery.
2. Each ***inferior hypophyseal artery*** divides into medial and lateral branches which join one another to form an arterial ring around the posterior lobe. Branches from this ring supply the posterior lobe and also anastomose with branches from the superior hypophyseal artery.
3. The anterior lobe or pars distalis is supplied exclusively by ***portal vessels*** arising from capillary tufts formed by the superior hypophyseal arteries. The long portal vessels drain the median eminence and the upper infundibulum, and the short portal vessels drain the lower infundibulum.
4. The hypothalamohypophyseal tract begins in the preoptic and paraventricular nuclei of the hypothalamus. Its short fibres terminate in relation to capillary tufts of portal vessels, providing the possibility for a neural control of the secretory activity of the anterior lobe. The long fibres of the neurosecretory tract pass to the posterior lobe and terminate near vascular sinusoids.

   The hormones related to the posterior lobe are:
   a. *Vasopressin*, antidiuretic hormone (ADH) which acts on kidney tubules.
   b. *Oxytocin*, which promotes contraction of the uterine and mammary smooth muscle.

These hormones are actually secreted by the hypothalamus, from where these are transported through the hypothalamohypophyseal tract to the posterior lobe of the gland.

Competency:
AN30.5 Explain effect of pituitary tumours on visual pathway.

CLINICAL ANATOMY

Pituitary tumours give rise to two main categories of symptoms:

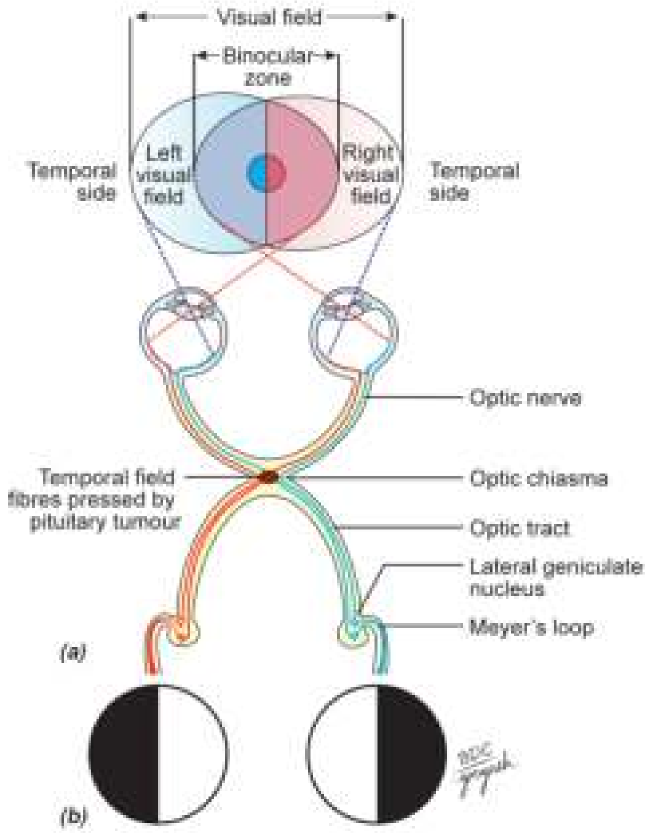
A. *General symptoms* due to pressure over surrounding structures:
   a. Sella turcica is enlarged in size.

b. Pressure over the central part of optic chiasma causes bitemporal hemianopia and tubular vision (Figs 12.14a and b).
c. Pressure over the hypothalamus may cause one of the hypothalamic syndromes like obesity of ***Frolich's syndrome*** in cases with Rathke's pouch tumours.
d. A large tumour may press upon the third ventricle, causing a rise in intracranial pressure.

B. *Specific symptoms* depending on the cell type of the tumour.
  a. Acidophil or eosinophil adenoma causes acromegaly in adults and gigantism in younger patients.
  b. Basophil adenoma causes Cushing's syndrome.
  c. Chromophobe adenoma causes effects of hypopituitarism.
  d. Posterior lobe damage causes diabetes insipidus, although the lesion in these cases usually lies in the hypothalamus.

DISSECTION

Identify diaphragma sellae over the hypophyseal fossa. Incise it radially and locate the hypophysis cerebri lodged in its fossa. Take it out and examine it in detail with the hand lens.


Visual field
Binocular zone
Temporal side
Left visual field
Right visual field
Temporal side
Optic nerve
Temporal field fibres pressed by pituitary tumour
Optic chiasma
Optic tract
Lateral geniculate nucleus
Meyer's loop
(a)
(b)

Figs 12.14a and b: Bitemporal hemianopia due to pressure of pituitary tumour on the central part of optic chiasma

TRIGEMINAL GANGLION

This is the *sensory ganglion* (***Gasserian ganglion***) of the 5th cranial nerve (Fig. 12.15). It is homologous with the dorsal nerve root ganglia of spinal nerves. All such ganglia are made up of pseudounipolar nerve cells, with a 'T'-shaped arrangement of their process; one process arises from the cell body which then divides into a central and a peripheral process.

The ganglion is crescentic or semilunar in shape, with its convexity directed anterolaterally.

Situation and Meningeal Relations

The ganglion lies on the *trigeminal impression*, on the anterior surface of the petrous temporal bone near its apex. It occupies a special space of dura mater, called the *trigeminal or* ***Meckel's cave***. There are two layers of dura below the ganglion. The cave is lined by pia-arachnoid, so that the ganglion along with the motor root of the trigeminal nerve is surrounded by CSF. The ganglion lies at a depth of about 5 cm from the preauricular point.

Relations (Fig. 12.15)

Medially
1. Internal carotid artery
2. Posterior part of cavernous sinus

Laterally: Middle meningeal artery

Superiorly: Parahippocampal gyrus

Inferiorly
1. Motor root of trigeminal nerve
2. Greater petrosal nerve
3. Apex of the petrous temporal bone
4. The foramen lacerum.

Associated Root and Branches

The central processes of the ganglion cells form the large ***sensory root*** of the trigeminal nerve which is attached to pons at its junction with the middle cerebellar peduncle.

The peripheral processes of the ganglion cells form three divisions of the trigeminal nerve, namely the

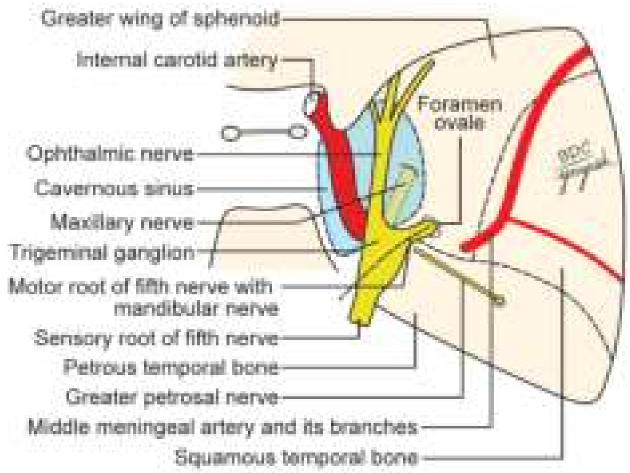

Greater wing of sphenoid
Internal carotid artery
Foramen ovale
Ophthalmic nerve
Cavernous sinus
Maxillary nerve
Trigeminal ganglion
Motor root of fifth nerve with mandibular nerve
Sensory root of fifth nerve
Petrous temporal bone
Greater petrosal nerve
Middle meningeal artery and its branches
Squamous temporal bone

Fig. 12.15: Superior view of the middle cranial fossa showing some of its contents

Ophthalmic V1 (*see* Chapter 13), maxillary V2 (*see* Chapter 15) and mandibular V3 (*see* Chapter 6).

The small ***motor root*** of the trigeminal nerve is attached to the pons superomedial to the sensory root. It passes under the ganglion from its medial to the lateral side, and joins the mandibular nerve at the foramen ovale.

Blood Supply

The ganglion is supplied by twigs from:

1. Internal carotid
2. Middle meningeal
3. Accessory meningeal arteries
4. By the meningeal branch of the ascending pharyngeal artery.

CLINICAL ANATOMY

- Intractable facial pain due to trigeminal neuralgia or carcinomatosis may be abolished by injecting alcohol into the ganglion. Sometimes cutting of the sensory root is necessary (Fig. 12.16).
- Congenital cutaneous naevi on the face (port wine stains) map out accurately the areas supplied by one or more divisions of the V cranial nerve.

DISSECTION

Identify trigeminal ganglion situated on the anterior surface of petrous temporal bone near its apex. Define the three branches emerging from its convex anterior surface.

MIDDLE MENINGEAL ARTERY

It is the largest branch of 1st part of maxillary artery.

Course: It ascends upward in the infratemporal fossa, deep to lateral pterygoid muscle. Here, it is encircled by two roots of auriculotemporal nerve. It enters the middle cranial fossa through foramen spinosum.

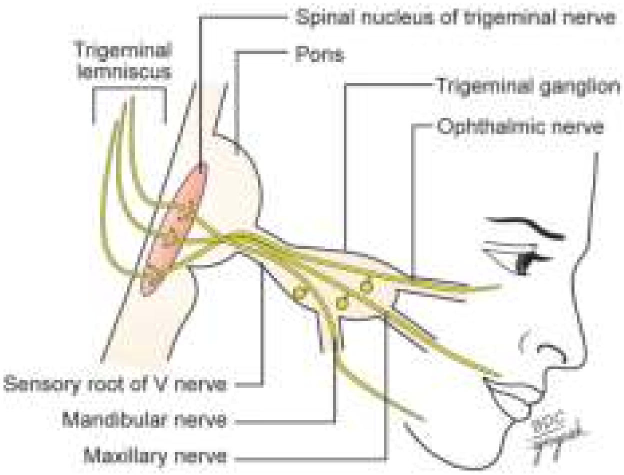


Fig. 12.16: Pathways of fibres from the skin of face

In the middle cranial fossa, the artery runs forward and laterally in extradural course and terminates by dividing into two terminal branches:

1. Anterior or frontal
2. Posterior or parietal

Branches

1. Frontal or anterior branch: It crosses pterion and supplies meninges.
2. Parietal or posterior branch: It also supplies meninges.
3. Ganglion branch to trigeminal ganglion.
4. Petrosal branch to hiatus for the greater petrosal nerve.
5. Superior tympanic branch to tensor tympani muscle
6. Temporal branches to temporal fossa.

CLINICAL ANATOMY

- The middle meningeal artery is of great surgical importance because it can be torn in head injuries resulting in ***extradural haemorrhage***. *The frontal* or *anterior branch* is commonly involved. The haematoma presses on the motor area, giving rise to hemiplegia of the opposite side. The anterior division can be approached surgically by making a hole in the skull over the pterion, 4 cm above the midpoint of the zygomatic arch.
- Rarely, the parietal or posterior branch is implicated, causing contralateral deafness. In this case, the hole is made at a point 4 cm above and 4 cm behind the external acoustic meatus.

DISSECTION

Dissect the middle meningeal artery which enters the skull through foramen spinosum. It is an important artery for the supply of endocranium, inner table of skull and diploe. Examine the other structures seen in cranial fossae after removal of brain. These are the cranial nerves, internal carotid artery, petrosal nerves and fourth part of vertebral artery.

Competency:
AN30.1 Describe the cranial fossae and identify related structures.

OTHER STRUCTURES SEEN IN CRANIAL FOSSAE AFTER REMOVAL OF BRAIN

Various Structures

The structures seen after removal of the brain are:

- 12 cranial nerves
- Four petrosal nerves
- Cavernous part of internal carotid artery
- 4th part of the vertebral artery.

DISSECTION

Following structures are seen in the anterior cranial fossa: Crista galli, cribriform plate of ethmoid, orbital part of frontal bone, and lesser wing of sphenoid.

Following structures are seen in the middle cranial fossa: Middle meningeal vessels, diaphragma sellae pierced by infundibulum, oculomotor nerves, internal carotid arteries, optic nerve, posterior cerebral artery, and great cerebral vein.

Following structures are seen in the posterior cranial fossa: Facial, vestibulocochlear, glossopharyngeal, vagus, accessory, hypoglossal nerves, vertebral arteries, and spinal root of accessory nerve.

Cranial Nerves (Plate 12.2, Fig. 12.17)

1. *First* or ***olfactory nerve*** is seen in the form of 15 to 20 filaments on each side that pierce the cribriform plate of the ethmoid bone.
2. *Second* or ***optic nerve*** passes through the optic canal with the ophthalmic artery (Fig. 12.17).
3. *Third* or ***oculomotor*** and *fourth* or ***trochlear nerves*** pierce the posterior part of the roof of the cavernous sinus formed by crossing of the free and attached margins of the tentorium cerebelli; next they run in the lateral wall of the cavernous sinus. They enter the orbit through the superior orbital fissure.
4. *Fifth* or ***trigeminal nerve*** has a large sensory root and a small motor root. The roots cross the apex of the petrous temporal bone beneath the superior petrosal sinus, to enter the middle cranial fossa.
5. *Sixth* or ***abducent nerve*** pierces the lower part of the posterior wall of the cavernous sinus near the apex of the petrous temporal bone. It runs forwards by the side of the dorsum sellae beneath the petrosphenoidal ligament to reach the centre of the cavernous sinus.
6. *Seventh* or ***facial*** and *eighth* or *statoacoustic* or ***vestibulocochlear nerves*** pass through the internal acoustic meatus with the labyrinthine vessels.
7. *Ninth* or ***glossopharyngeal***, *tenth* or ***vagus*** and *eleventh* or ***accessory nerves*** pierce the dura mater at the jugular foramen and pass out through it. The *glossopharyngeal* nerve is enclosed in a separate sheath of dura mater, while vagus and accessory nerves are enclosed in one sheath. The spinal part of the accessory nerve first enters the posterior cranial fossa through the foramen magnum, and then passes out through the jugular foramen along with cranial part.
8. The two parts of the *twelfth* or ***hypoglossal nerve*** pierce the dura mater separately opposite the hypoglossal canal and then pass out through it.

Petrosal Nerves

Greater Petrosal Nerve

It carries gustatory and parasympathetic fibres. It arises from the geniculate ganglion of the facial nerve, and enters the middle cranial fossa through the hiatus for the greater petrosal nerve on the anterior surface of the petrous temporal bone. It proceeds towards the foramen lacerum, where it joins the deep petrosal nerve which carries sympathetic fibres to form the nerve of the pterygoid canal (*see* Table A.2).

The nerve of the pterygoid canal passes through the pterygoid canal to reach the pterygopalatine ganglion. The parasympathetic fibres relay in this ganglion. Postganglionic parasympathetic fibres arising in the ganglion ultimately supply the lacrimal gland and the mucosal glands of the nose, palate and pharynx. The

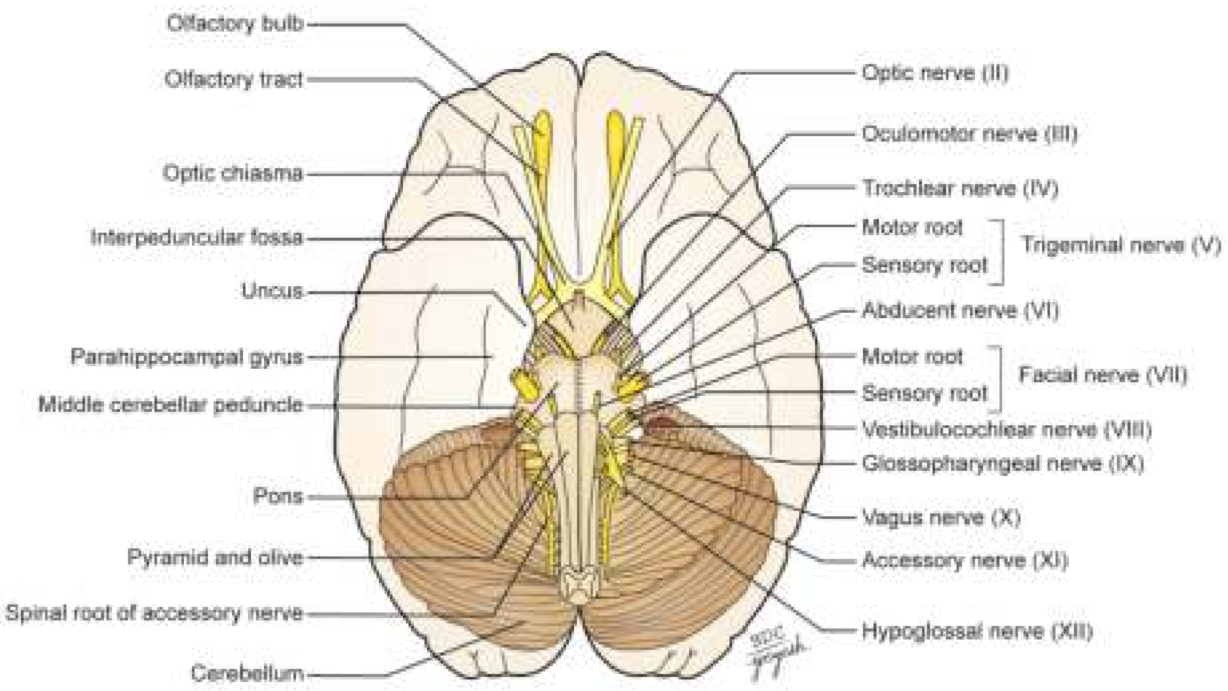
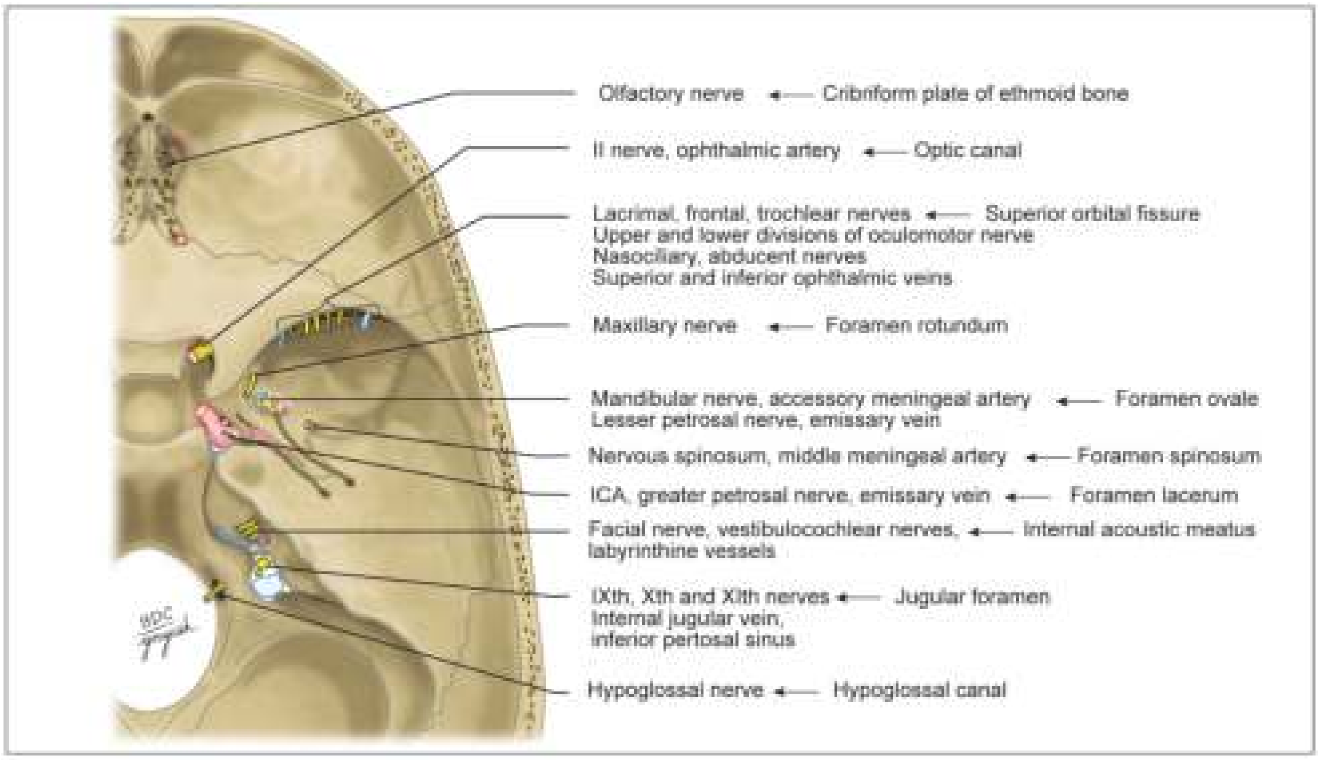

Olfactory bulb
Olfactory tract
Optic chiasma
Interpeduncular fossa
Uncus
Parahippocampal gyrus
Middle cerebellar peduncle
Pons
Pyramid and olive
Spinal root of accessory nerve
Cerebellum
Optic nerve (II)
Oculomotor nerve (III)
Trochlear nerve (IV)
Motor root
Sensory root
Trigeminal nerve (V)
Abducent nerve (VI)
Motor root
Sensory root
Facial nerve (VII)
Vestibulocochlear nerve (VIII)
Glossopharyngeal nerve (IX)
Vagus nerve (X)
Accessory nerve (XI)
Hypoglossal nerve (XII)

Fig. 12.17: Highlights of the cranial nerves

Plate 12.2: Identification of cranial nerve in cranial fossae


Olfactory nerve ← Cribriform plate of ethmoid bone
II nerve, ophthalmic artery ← Optic canal
Lacrimal, frontal, trochlear nerves ← Superior orbital fissure
Upper and lower divisions of oculomotor nerve
Nasociliary, abducent nerves
Superior and inferior ophthalmic veins
Maxillary nerve ← Foramen rotundum
Mandibular nerve, accessory meningeal artery ← Foramen ovale
Lesser petrosal nerve, emissary vein
Nervous spinosum, middle meningeal artery ← Foramen spinosum
ICA, greater petrosal nerve, emissary vein ← Foramen lacerum
Facial nerve, vestibulocochlear nerves, ← Internal acoustic meatus
labyrinthine vessels
IXth, Xth and XIth nerves ← Jugular foramen
Internal jugular vein,
inferior pertosal sinus
Hypoglossal nerve ← Hypoglossal canal
BDC

gustatory or taste fibres do not relay in the ganglion and are distributed to the palate.

Deep Petrosal Nerve

It is sympathetic in nature. It is a branch of the sympathetic plexus around the internal carotid artery. It contains postganglionic fibres from the superior cervical sympathetic ganglion. The nerve joins the greater petrosal nerve to form the nerve of the pterygoid canal. The sympathetic fibres are distributed through the branches of the pterygopalatine ganglion.

Lesser Petrosal Nerve

It is parasympathetic in nature. It is a branch of the tympanic plexus, deriving its preganglionic parasympathetic fibres from the tympanic branch of the glossopharyngeal nerve. It emerges through the hiatus for the lesser petrosal nerve, situated just lateral to the hiatus for the greater petrosal nerve, passes out of the skull through the foramen ovale, and ends in the otic ganglion. Postganglionic fibres arising in the ganglion supply the parotid gland through the auriculotemporal nerve (*see* Table A.2 in Appendix).

External Petrosal Nerve

It is sympathetic in nature. It is an inconstant branch from the sympathetic plexus around the middle meningeal artery to the geniculate ganglion of the facial nerve.

Note: Internal carotid artery begins in the neck as one of the terminal branches of the common carotid artery at the level of the upper border of the thyroid cartilage. Its course is divided into the four parts: Cervical, petrous, cavernous and cerebral (*see* Chapter 8 for details).

Fourth part of the vertebral artery enters the posterior cranial fossa through the foramen magnum after piercing the dura mater near the skull. It has been studied in Chapter 9.

VIDEO

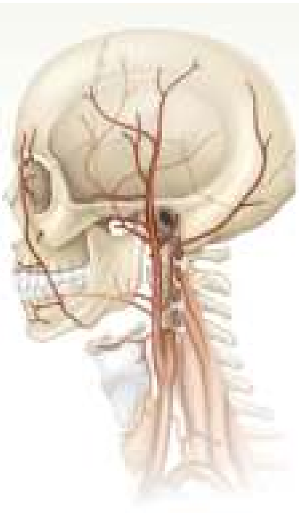
Video 3.12 Cranial Cavity: Introduction, Dura mater, venous sinuses, cavernous sinus.

Facts to Remember

- Meningeal layer of dura mater forms falx cerebri and falx cerebelli in sagittal plane and tentorium cerebelli and diaphragma sellae in horizontal plane.
- Only spinal ganglia present in the cranial cavity is the trigeminal ganglion.
- Only mixed branch of trigeminal is the mandibular branch. The other two are purely sensory.
- Anterior branch of middle meningeal artery lies on the inner aspect of *pterion* and is liable to injury, leading to extradural haemorrhage.
- Trigeminal ganglion lies in Meckel's cave – formed by meningeal layer of dura mater.
- Rathke's pouch give rise to adenohypophysis.
- Herring bodies are located in neurohypophysis and they are the nerve terminals of hypothalamo-hypophyseal tracts containing vasopressin and antidiuretic hormones.

BDC's Anatomy *e*-book

1. Molecular regulation of development of pituitary gland
2. Trigeminal nerve
3. Further reading
4. Viva voce questions



Chapter

13

Contents of the Orbit

BONY ORBITS

These are pyramidal bony cavities, situated one on each side of the root of the nose. They provide sockets for rotatory movements of the eyeballs. They also protect the eyeballs (Figs 13.1 and 13.2, Plate 13.1).

The long or ***orbital axis*** of the orbit passes backwards and medially. The medial walls of the two orbits are parallel and the lateral walls are set at right angles to each other (Fig. 13.1). The axis passing through centres of anterior and posterior poles of the eyeball is known as ***visual axis***. It makes an angle of 20–25° with the orbital axis.

BOUNDARIES OF BONY ORBIT

Each orbit resembles a four-sided pyramid. Thus, it has (Plate 13.1, Fig. 13.2):

1. *Apex* – situated at the posterior end of orbit at the medial end of superior orbital fissure.
2. *Base* – seen as the orbital opening on the face.
3. *Four walls*: Roof, floor, lateral and medial walls.

Roof

It is concave from side-to-side. It is formed:

1. Mainly by the orbital plate of the frontal bone.
2. It is completed posteriorly by the lesser wing of the sphenoid.

Features

1. ***Lacrimal fossa***, placed anterolaterally, lodges the lacrimal gland.
2. ***Optic canal*** lies posteriorly, at the junction of the roof and medial wall.
3. ***Trochlear fossa*** lies anteromedially. It provides attachment to the fibrous pulley or trochlea for the tendon of the *superior oblique muscle.*

Lateral Wall

This is the thickest and strongest of all the walls of the orbit. It is formed:

1. By the anterior surface of the greater wing of the sphenoid bone, posteriorly.

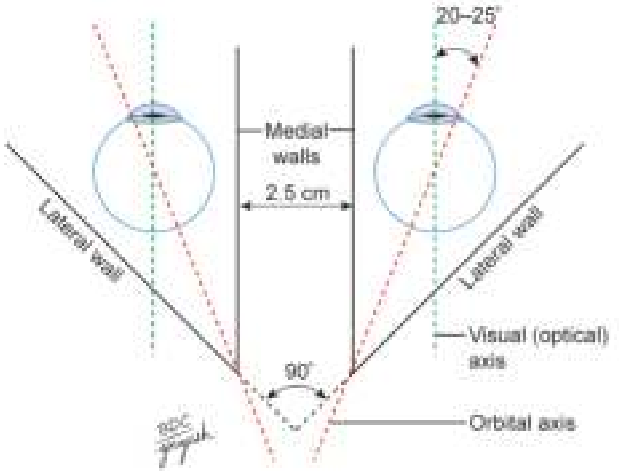


Fig. 13.1: Visual and orbital axes

2. By the orbital surface of the frontal process of the zygomatic bone, anteriorly.

Features

1. ***Superior orbital fissure*** occupies the posterior part of the junction between the roof and lateral wall.
2. ***Foramen for the zygomatic nerve*** is seen in the zygomatic bone.
3. ***Whitnall's* or *zygomatic tubercle*** is a palpable elevation on the zygomatic bone just within the orbital margin. It provides attachment to the lateral check ligament of eyeball.

Floor

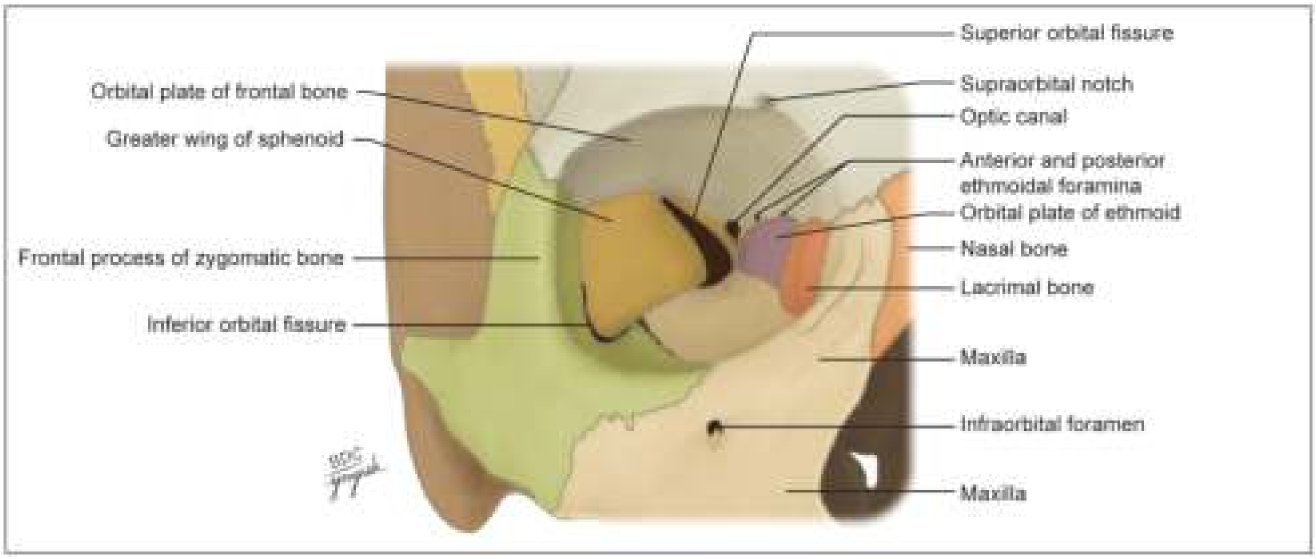
It slopes upwards and medially to join the medial wall. It is formed:

1. Mainly by the orbital surface of the maxilla.
2. By the lower part of the orbital surface of the zygomatic bone, anterolaterally.
3. Orbital process of the palatine bone, at the posterior angle.

Features

1. ***Inferior orbital fissure*** occupies the posterior part of the junction between the lateral wall and floor. Through this fissure, the orbit communicates with

Plate 13.1: Bony orbit


Orbital plate of frontal bone
Greater wing of sphenoid
Frontal process of zygomatic bone
Inferior orbital fissure
Superior orbital fissure
Supraorbital notch
Optic canal
Anterior and posterior ethmoidal foramina
Orbital plate of ethmoid
Nasal bone
Lacrimal bone
Maxilla
Infraorbital foramen
Maxilla
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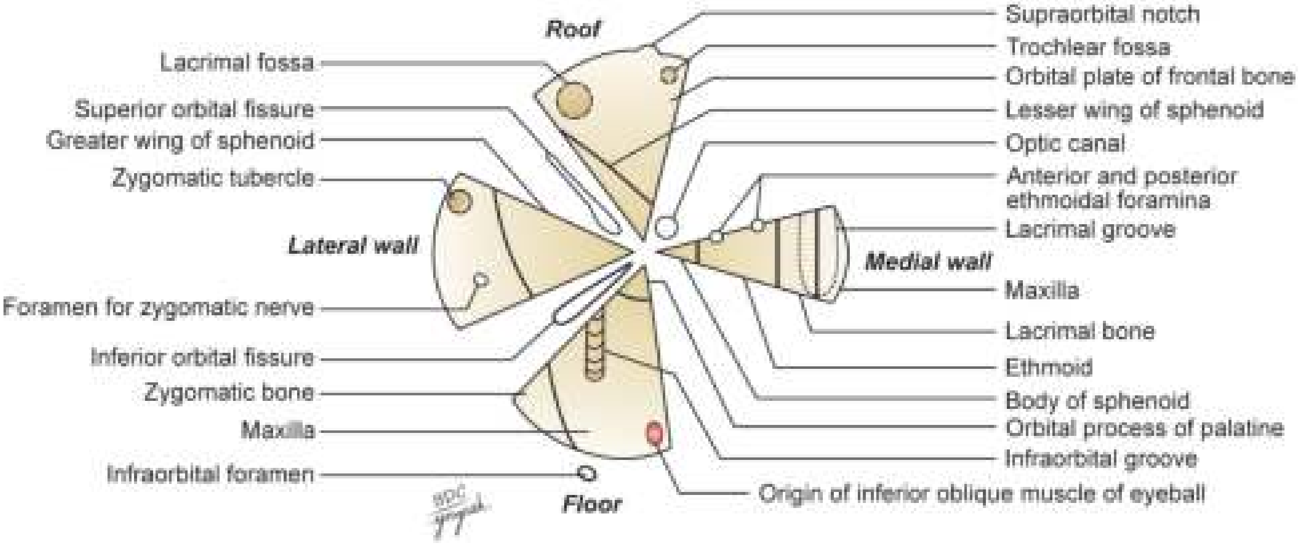

Roof
Lacrimal fossa
Superior orbital fissure
Greater wing of sphenoid
Zygomatic tubercle
Lateral wall
Foramen for zygomatic nerve
Inferior orbital fissure
Zygomatic bone
Maxilla
Infraorbital foramen
Floor
Supraorbital notch
Trochlear fossa
Orbital plate of frontal bone
Lesser wing of sphenoid
Optic canal
Anterior and posterior ethmoidal foramina
Lacrimal groove
Medial wall
Maxilla
Lacrimal bone
Ethmoid
Body of sphenoid
Orbital process of palatine
Infraorbital groove
Origin of inferior oblique muscle of eyeball
BDC

Fig. 13.2: Features of bony orbit. The four walls of the pyramidal cavity have been separated to show their details

the infratemporal fossa anteriorly and with the pterygopalatine fossa posteriorly.

2. ***Infraorbital groove*** runs forwards in relation to the floor.
3. A small depression on anteromedial part of the floor gives origin to *inferior oblique muscle*.

Medial Wall

It is very thin. From before backwards, it is formed by:

1. Frontal process of the maxilla
2. Lacrimal bone
3. Orbital plate of the ethmoid
4. Body of the sphenoid bone.

Features

1. The ***lacrimal groove*** lies anteriorly on the medial wall. It is bounded anteriorly by the anterior lacrimal crest of the frontal process of the maxilla, and posteriorly by posterior lacrimal crest of the lacrimal bone. The floor of the groove is formed by the maxilla in front and by the lacrimal bone behind. The groove lodges the lacrimal sac which lies deep to the lacrimal fascia bridging the lacrimal groove. The groove leads inferiorly, through the nasolacrimal duct, to the inferior meatus of the nose.
2. ***Anterior and posterior ethmoidal foramina*** lie on the frontoethmoidal suture, at the junction of the roof and medial wall.

Foramina in Relation to the Orbit

1. *Inferior orbital fissure* transmits:
   a. *Zygomatic nerve*,
   b. *Orbital branches of the pterygopalatine ganglion*,
   c. *Infraorbital nerve and vessels*, and the communication between the inferior ophthalmic vein and the pterygoid plexus of veins.

2. *Infraorbital groove and canal* transmit the corresponding nerve and vessels.
3. *Zygomatic foramen* transmits the zygomatic nerve.
4. *Anterior ethmoidal foramen* transmits the corresponding nerve and vessels.
5. *Posterior ethmoidal foramen* only transmits vessels of same name.

Note: The structures passing through the optic canal and through the superior orbital fissure have been described in cranial fossae.

CONTENTS OF ORBITS

Contents

1. *Eyeball:* Eyeball occupies anterior one-third of orbit (For details, *see* Chapter 19).
2. *Fascia:* Orbital and bulbar.
3. *Muscles:* Extraocular and intraocular.
4. *Vessels:* Ophthalmic artery, superior and inferior ophthalmic veins, and lymphatics.
5. *Nerves:* Optic, oculomotor, trochlear and abducent; branches of ophthalmic and maxillary nerves, and sympathetic nerves.
6. *Lacrimal gland* (For details, *see* Chapter 2).
7. *Orbital fat.*

DISSECTION

Strip the endosteum from the floor of the anterior cranial fossa. Gently break the orbital plate of frontal bone forming the roof of the orbit and remove it in pieces so that orbital periosteum is clearly visible. Medially, the ethmoidal vessels and nerves should be preserved. Posteriorly, identify the optic canal and superior orbital fissure and structures traversing these. Define the orbital fascia and fascial sheath of eyeball.

Divide the orbital periosteum along the middle of the orbit anteroposteriorly. Cut through it horizontally close to anterior margin of orbit.

Orbital Fascia or Periorbita

It forms the *periosteum* of the bony orbit (Fig. 13.3).

Features

1. Due to the loose connection to bone, it can be easily stripped. Posteriorly, it is continuous with the dura mater and with the sheath of the optic nerve. Anteriorly, it is continuous with the periosteum lining the bones around the orbital margin.
2. There is a gap in the periorbita over the inferior orbital fissure. This gap is bridged by connective tissue with some smooth muscle fibres in it. These fibres constitute the ***orbitalis muscle***.
3. At the upper and lower margins of the orbit, the orbital fascia sends off flap-like continuations into the eyelids. These extensions form the ***orbital septum***.
4. A process of the fascia holds the fibrous ***pulley*** of the tendon of the superior oblique muscle in place.

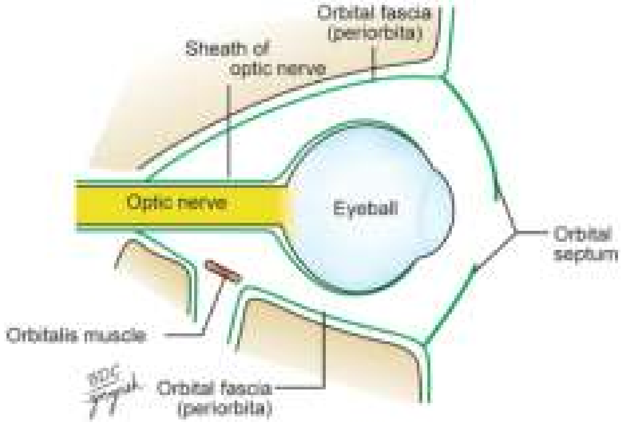

Orbital fascia (periorbita)
Sheath of optic nerve
Optic nerve
Eyeball
Orbital septum
Orbitalis muscle
Orbital fascia (periorbita)

Fig. 13.3: Orbital fascia and fascial sheath of the eyeball as seen in a parasagittal section

5. Another process forms the ***lacrimal fascia*** which bridges the lacrimal groove.

Note: ***Orbitalis muscle*** is a smooth muscle that bridges the inferior orbital fissure. It is considered a rudimentary muscle. It is fused with the orbital fascia. It receives sympathetic innervation, and its function is not known.

Fascial Sheath of Eyeball or Bulbar Fascia

(Figs 13.4 and 13.5)

1. ***Tenon's capsule*** forms a thin, loose membranous sheath around the eyeball, extending from the optic nerve to the sclerocorneal junction or limbus. It is separated from the sclera by the episcleral space which is traversed by delicate fibrous bands. The eyeball can freely move within this sheath.
2. This *sheath* is pierced by:
   a. Tendons of the various extraocular muscles.
   b. Ciliary vessels and nerves around the entrance of the optic nerve.
3. This sheath gives off a number of expansions.
   a. *Tubular sheath* covers each orbital muscle.

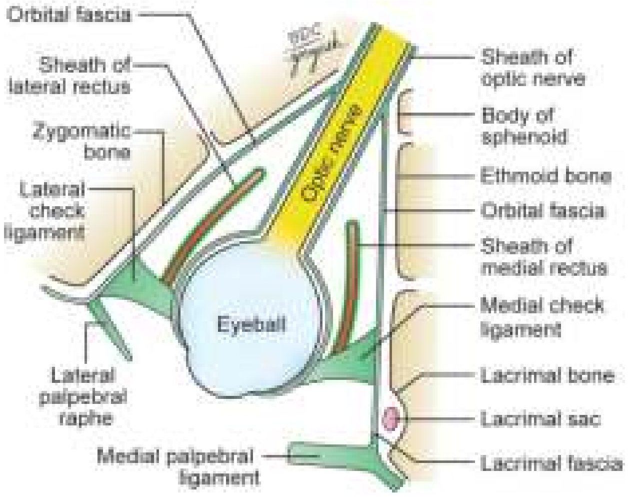

Orbital fascia
Sheath of lateral rectus
Zygomatic bone
Lateral check ligament
Lateral palpebral raphe
Medial palpebral ligament
Optic nerve
Eyeball
Sheath of optic nerve
Body of sphenoid
Ethmoid bone
Orbital fascia
Sheath of medial rectus
Medial check ligament
Lacrimal bone
Lacrimal sac
Lacrimal fascia

Fig. 13.4: Orbital fascia and fascial sheath of the eyeball as seen in the transverse section

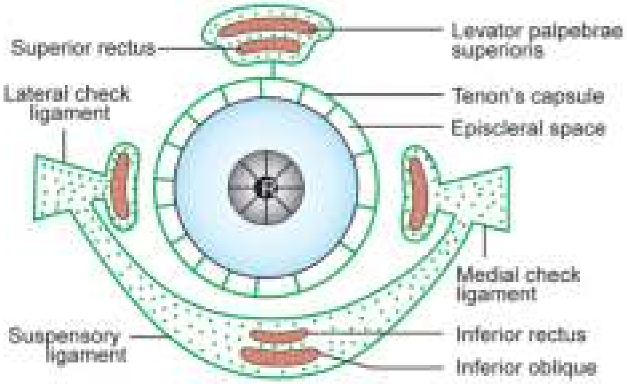


Fig. 13.5: Fascial sheath of the eyeball as seen in coronal section

   b. ***Medial check ligament*** is a strong triangular expansion from the sheath of the medial rectus muscle; it is attached to the lacrimal bone.
   c. ***Lateral check ligament*** is a strong triangular expansion from the sheath of the lateral rectus muscle; it is attached to the zygomatic bone (Fig. 13.4).

4. ***Suspensory ligament of Lockwood:*** The lower part of Tenon's capsule is thickened, and is named the *suspensory ligament of the eye* or the *suspensory ligament of Lockwood* (Fig. 13.5). It is expanded in the centre and narrow at its extremities, and is slung like a hammock below the eyeball. It is formed by union of the margins of the sheaths of the inferior rectus and the inferior oblique muscles with the medial and lateral check ligaments.

DISSECTION

Identify and preserve the trochlear nerve entering the superior oblique muscle in the superomedial angle of the orbit. Find the frontal nerve lying in the midline on the levator palpebrae superioris. It divides into two terminal divisions in the anterior part of orbit.

Beneath the levator palpebrae superioris is the superior rectus muscle. The upper division of oculomotor nerve lies between these two muscles. Along the lateral wall of the orbit, look for lacrimal nerve and artery to reach the superolateral corner of the orbit.

Follow the tendon of superior oblique muscle passing superolaterally beneath the superior rectus to be inserted into sclera behind the equator. After identification, divide frontal nerve, levator palpebrae superioris and superior rectus in the middle of the orbit and reflect them apart. Identify the optic nerve and other structures crossing it. These are nasociliary nerve, ophthalmic artery and superior ophthalmic vein. With the optic nerve find two long ciliary nerves and 12–20 short ciliary nerves. Remove the orbital fat and look carefully in the posterior part of the interval between the optic nerve and lateral rectus muscle along the lateral wall of the orbit and identify the pinhead-sized ciliary ganglion. Trace the roots connecting it to the nasociliary nerve and nerve to inferior oblique muscle.

Lastly, identify the abducent nerve closely adherent to the medial surface of lateral rectus muscle. Incise the inferior fornix of conjunctiva and palpebral fascia. Elevate the eyeball and remove the fat and fascia to identify the origin of inferior oblique muscle from the floor of the orbit anteriorly.

Identify the levator palpebrae superioris and superior rectus above the eyeball, superior oblique superomedially, medial rectus medially, lateral rectus laterally, and inferior rectus inferiorly.

The voluntary muscles are miniature ribbon muscles, having short tendons of origin and long tendons of insertion.

Competency:
AN31.1 Describe and identify extraocular muscles of eyeball, along with a note on its attachment, action and clinical anatomy.

EXTRAOCULAR MUSCLES

The extraocular muscles of the eyeball are classified into two groups: Involuntary and voluntary (Plate 13.2, Flowchart 13.1).

Involuntary Muscles

1. ***Superior tarsal muscle*** is the deeper portion of the levator palpebrae superioris. It is inserted on the upper margin of the superior tarsus. It elevates the upper eyelid.
2. ***Inferior tarsal muscle*** extends from the fascial sheath of the inferior rectus and inferior oblique to the lower margin of the inferior tarsus. It possibly depresses the lower eyelid.
3. ***Orbitalis*** bridges the inferior orbital fissure. Its action is uncertain.

Nerve Supply

Involuntary muscles of the eye are supplied by postganglionic sympathetic fibres from superior cervical ganglion.

Voluntary Extraocular Muscles

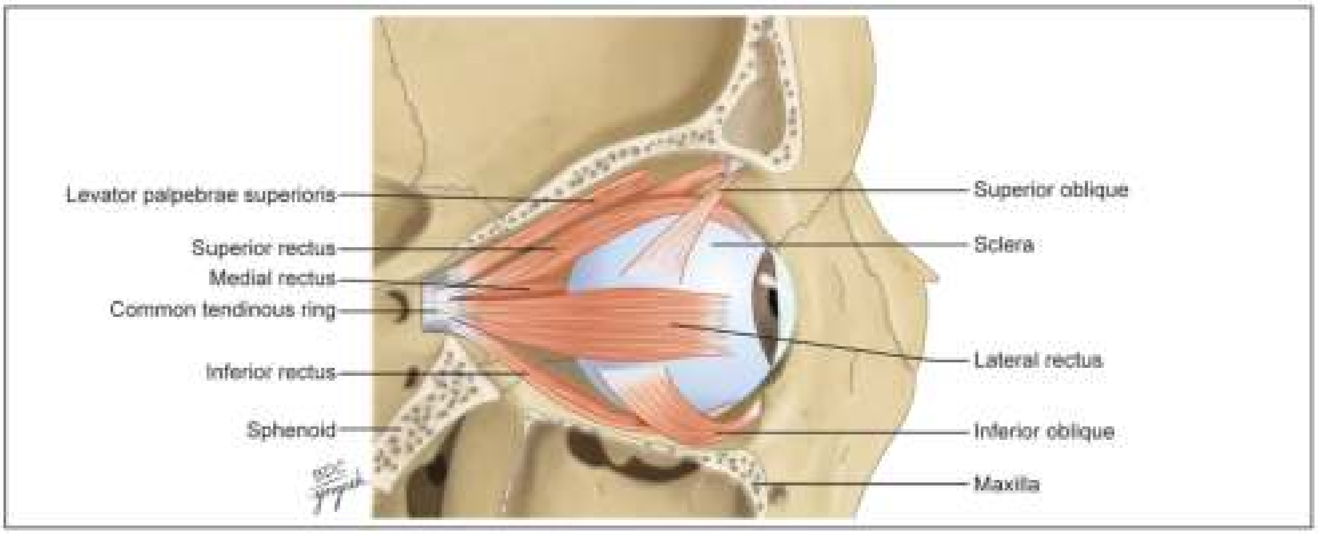
1. Four recti:
   a. Superior rectus
   b. Inferior rectus
   c. Medial rectus
   d. Lateral rectus
2. Two obliques:
   a. Superior oblique
   b. Inferior oblique
3. Levator palpebrae superioris.

Recti Muscles

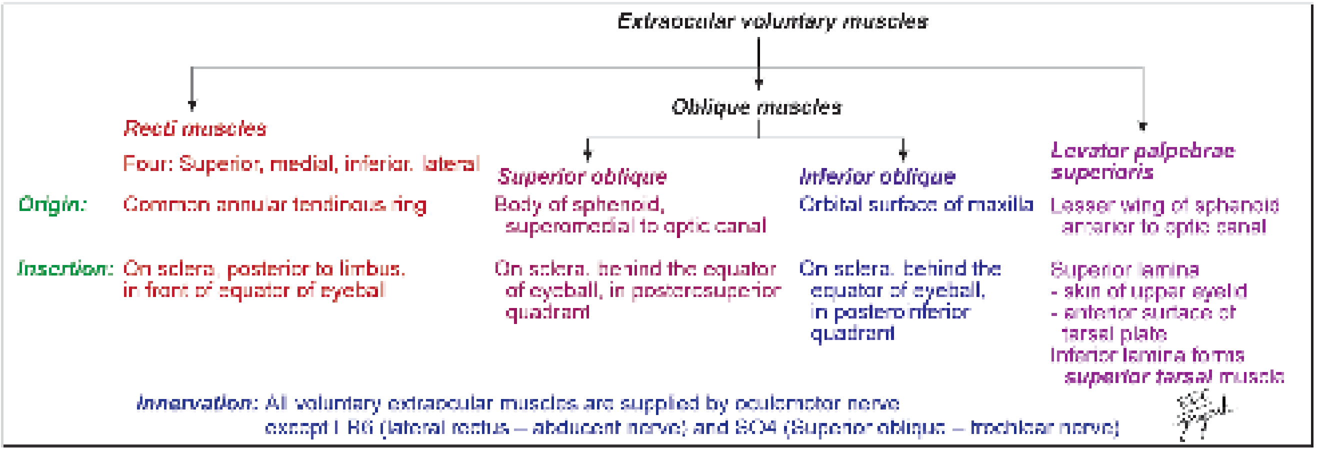
Origin

1. All recti arise from a *common annular tendon* or ***tendinous ring*** **of Zinn**. The ring is attached to the middle part of superior orbital fissure and around optic canal (Fig. 13.6).

Plate 13.2: Extraocular muscles (right lateral view, parasagittal section, lateral wall of orbit is removed to visualize its interior)


Levator palpebrae superioris
Superior rectus
Medial rectus
Common tendinous ring
Inferior rectus
Sphenoid
Superior oblique
Sclera
Lateral rectus
Inferior oblique
Maxilla

Flowchart 13.1: Extraocular voluntary muscles


Extraocular voluntary muscles
Oblique muscles

	Recti muscles	*Superior oblique*	*Inferior oblique*	*Levator palpebrae superioris*
	Four: Superior, medial, inferior, lateral			
Origin:	Common annular tendinous ring	Body of sphenoid, superomedial to optic canal	Orbital surface of maxilla	Lesser wing of sphenoid anterior to optic canal
Insertion:	On sclera, posterior to limbus, in front of equator of eyeball	On sclera, behind the equator of eyeball, in posterosuperior quadrant	On sclera, behind the equator of eyeball, in posteroinferior quadrant	Superior lamina - skin of upper eyelid - anterior surface of tarsal plate Inferior lamina forms *superior tarsal* muscle

Innervation: All voluntary extraocular muscles are supplied by oculomotor nerve except LR6 (lateral rectus – abducent nerve) and SO4 (Superior oblique – trochlear nerve)

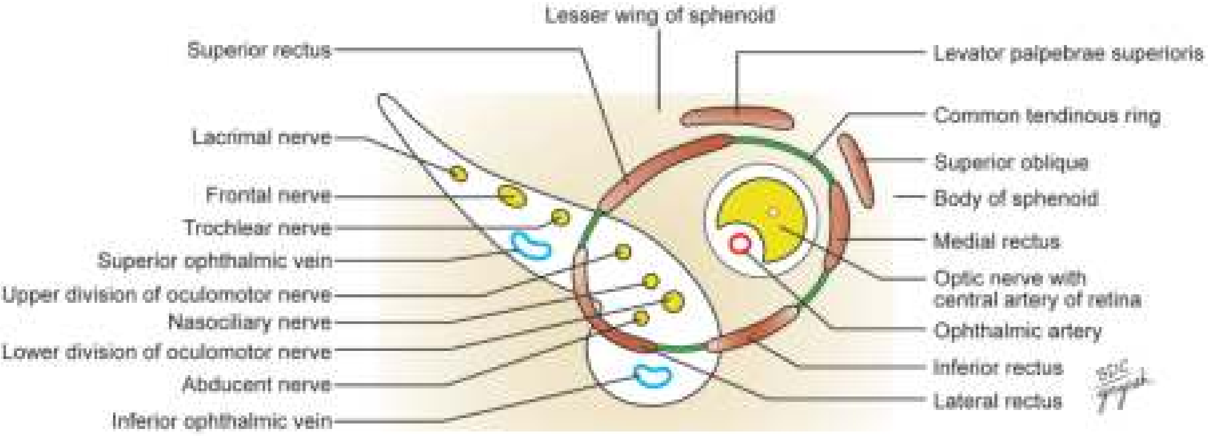

Lesser wing of sphenoid
Superior rectus
Lacrimal nerve
Frontal nerve
Trochlear nerve
Superior ophthalmic vein
Upper division of oculomotor nerve
Nasociliary nerve
Lower division of oculomotor nerve
Abducent nerve
Inferior ophthalmic vein
Levator palpebrae superioris
Common tendinous ring
Superior oblique
Body of sphenoid
Medial rectus
Optic nerve with central artery of retina
Ophthalmic artery
Inferior rectus
Lateral rectus

Fig. 13.6: Apical part of the orbit showing the origin of the extraocular muscles, the common tendinous ring and the structures passing through superior orbital fissure (seen from front)

2. The lateral rectus has an additional small tendinous head which arises from the orbital surface of the greater wing of the sphenoid bone lateral to the tendinous ring. Through the gap between the two heads abducent nerve passes.

Insertion: The recti are inserted into the sclera, a little posterior to the limbus (corneoscleral junction). The average distances of the insertions from the cornea are: Superior 7.7 mm; inferior 6.5 mm, medial 5.5 mm; lateral 6.9 mm (Fig. 13.7).

Oblique Muscles

Origin

1. The superior oblique arises from the undersurface of lesser wing of the sphenoid, superomedial to the optic canal (Fig. 13.6).
2. The inferior oblique arises from the orbital surface of the maxilla, lateral to the lacrimal groove. The muscle is situated near the anterior margin of the orbit.

Insertion (Fig. 13.8)

1. The tendon of the superior oblique passes through a fibrocartilaginous pulley attached to the trochlear fossa of the frontal bone. The tendon then passes laterally, downwards and backward below the superior rectus. It is inserted into the sclera behind the equator of the eyeball in posterolateral quadrant.
2. The inferior oblique is fleshy throughout. It passes laterally, upwards and backwards below the inferior rectus and then deep to the lateral rectus. The inferior oblique is inserted close to the superior oblique a little below and posterior to the latter.

Levator Palpebrae Superioris

Origin: The levator palpebrae superioris arises from the orbital surface of the lesser wing of the sphenoid bone, anterosuperior to the optic canal and to the origin of the superior rectus (Plate 13.2, Fig. 13.6).

Insertion: The flat tendon of the levator splits into a superior or voluntary and an inferior or involuntary lamellae. Superior lamella of the levator is inserted into the anterior surface of the superior tarsus, and into the skin of the upper eyelid. The inferior lamella (smooth part) is inserted into the upper margin of the superior tarsus and into superior conjunctival fornix.

Nerve Supply

1. The superior oblique is supplied by the IV cranial or trochlear nerve (SO4) (Fig. 13.9).

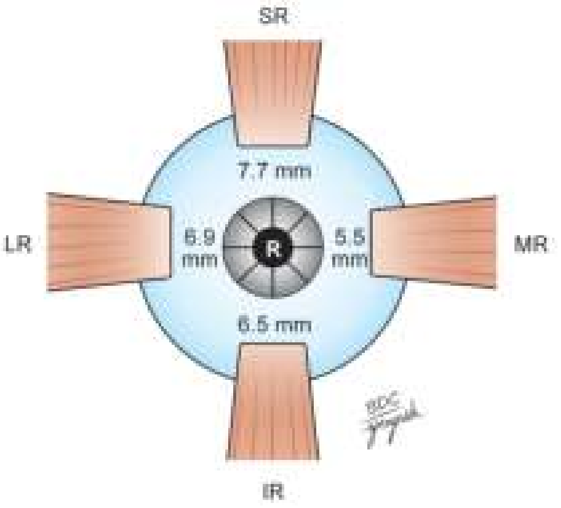

SR
7.7 mm
LR
6.9 mm
R
5.5 mm
MR
6.5 mm
IR

Fig. 13.7: Insertion of recti muscles

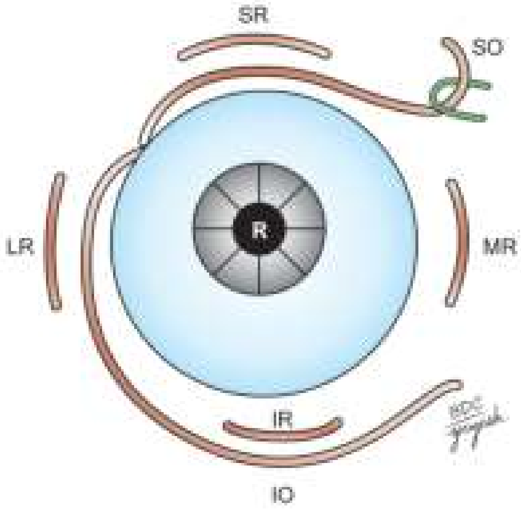

SR
SO
LR
R
MR
IR
IO

Fig. 13.8: Scheme to show the insertion of the oblique muscles of the eyeball

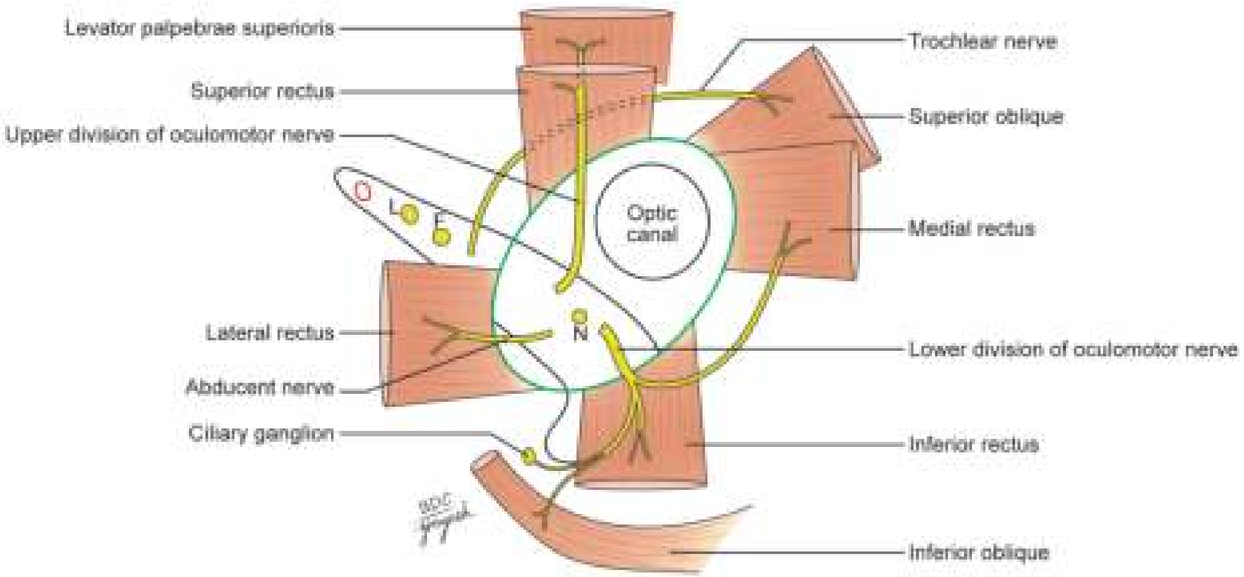

Levator palpebrae superioris
Superior rectus
Upper division of oculomotor nerve
O
L
F
Optic canal
N
Lateral rectus
Abducent nerve
Ciliary ganglion
Trochlear nerve
Superior oblique
Medial rectus
Lower division of oculomotor nerve
Inferior rectus
Inferior oblique

Fig. 13.9: Scheme showing the nerve supply of the extraocular muscles

2. The lateral rectus is supplied by the VI cranial or abducent nerve (LR6).
3. The remaining four and a half extraocular muscles; superior, inferior and medial recti; inferior oblique; and part of levator palpebrae superioris are all supplied by the III cranial or oculomotor nerve.

[*Mnemonics: Nerve supply of the* ***extraocular muscles: "LR6 SO4 rest 3"*** **L**ateral **r**ectus by **VI; S**uperior **o**blique by **IV; Rest** are by **III** cranial nerve, i.e. part of levator palpebrae superioris, superior rectus, medial rectus, inferior rectus and inferior oblique]

Actions (Figs 13.10 and 13.11)

1. ***Movements of the eyeball***
    a. *Around a transverse axis:*
        - Upward rotation or elevation (33°)
        - Downwards rotation or depression (33°)
    b. *Around a vertical axis:*
        - Medial rotation or adduction (50°)
        - Lateral rotation or abduction (50°)
    c. *Around an anteroposterior axis:*
        - Intorsion
        - Extorsion

    The rotatory movements of the eyeball upwards, downwards, medially or laterally, are defined in terms of the direction of movement of the centre of the pupil. The torsions are defined in terms of the direction of movement of the upper margin of the pupil at 12 o'clock position.

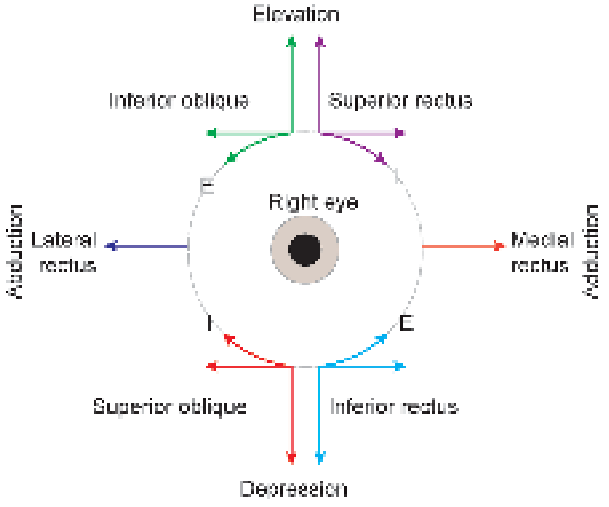

Elevation
Inferior oblique
Superior rectus
E
I
Right eye
Abduction
Lateral rectus
Medial rectus
Adduction
I
E
Superior oblique
Inferior rectus
Depression

Fig. 13.10: Actions of extraocular muscles (I: Intorsion, E: Extorsion)

2. ***Actions of individual muscles*** are shown in Table 13.1.
3. ***Single* or *pure movements*** are produced by combined actions of muscles. Similar actions get added together, while opposing actions cancel each other enabling pure movements (Table 13.2).
4. ***Combined movements of the eyes:*** The movements given above can take place in various combinations. Normally, movements of the two eyes are harmoniously coordinated. Such coordinated movements of both eyes are called ***conjugate ocular movements***.

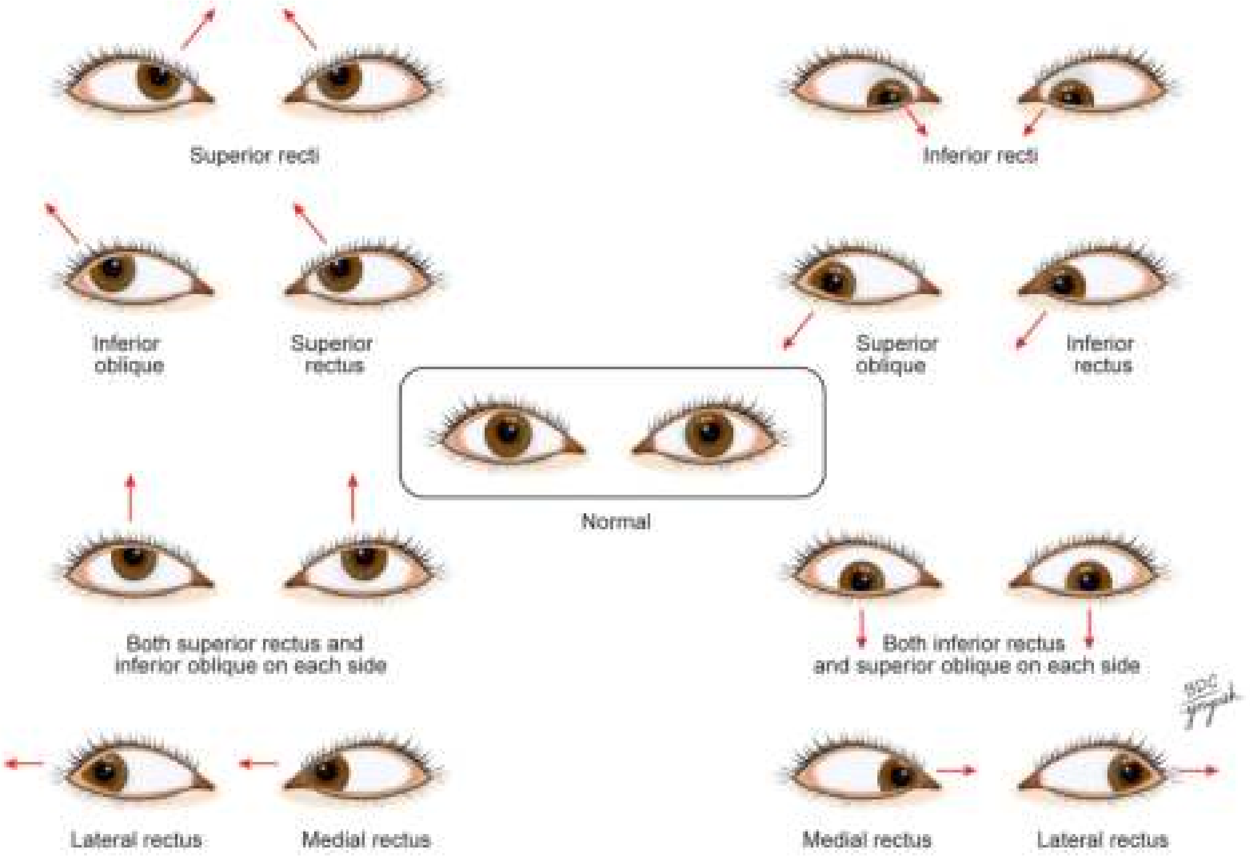

Superior recti
Inferior recti
Inferior oblique
Superior rectus
Superior oblique
Inferior rectus
Normal
Both superior rectus and inferior oblique on each side
Both inferior rectus and superior oblique on each side
Lateral rectus
Medial rectus
Medial rectus
Lateral rectus

Fig. 13.11: Muscles for conjugate movements of the eyes

TABLE 13.1: Actions of individual muscles

Muscle	*In primary position*
Superior oblique (SO)	Depression, abduction, intorsion
Inferior oblique (IO)	Elevation, abduction, extorsion
Inferior rectus (IR)	Depression, adduction, extorsion
Superior rectus (SR)	Elevation, adduction, intorsion
Medial rectus (MR)	Only adduction
Lateral rectus (LR)	Only abduction

TABLE 13.2: Single *or* pure movements of the eyeball

Movement of eyeball	*Muscles*
Upward rotation or elevation	Superior rectus, inferior oblique
Downward rotation or depression	Inferior rectus, superior oblique
Medial rotation or adduction	Medial rectus, superior rectus, inferior rectus
Lateral rotation or abduction	Lateral rectus, superior oblique, inferior oblique
Intorsion	Superior oblique, superior rectus
Extorsion	Inferior oblique, inferior rectus

CLINICAL ANATOMY

- Weakness or paralysis of a muscle causes ***squint*** or ***strabismus***, which may be concomitant or paralytic. Concomitant squint is congenital; there is no limitation of movement, and no diplopia (Fig. 13.12).
- In ***paralytic squint***, movements are limited, diplopia and vertigo are present, head is turned in the direction of the function of paralysed muscle, and there is a false orientation of the field of vision.
- ***Nystagmus*** is characterized by involuntary, rhythmical oscillatory movements of the eyes. This is due to incoordination of the ocular muscles. It may be either vestibular or cerebellar, or even congenital.

Note: Terms medial squint or internal strabismus and lateral squint or external strabismus are currently not in use.

Competency:

AN31.2 Describe and demonstrate vessels in the orbit.

VESSELS OF THE ORBIT

OPHTHALMIC ARTERY

Origin

The ophthalmic artery is a branch of the cerebral part of the internal carotid artery, given off medial to the anterior clinoid process close to the optic canal (Figs 13.13 and 13.14, Flowchart 13.2).

Course and Relations

1. The artery enters the orbit through the optic canal, lying inferolateral to the optic nerve. Both the artery and nerve lie in a common dural sheath.

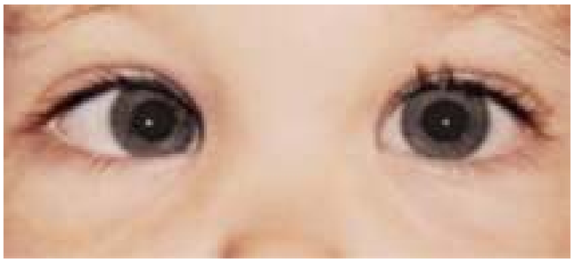
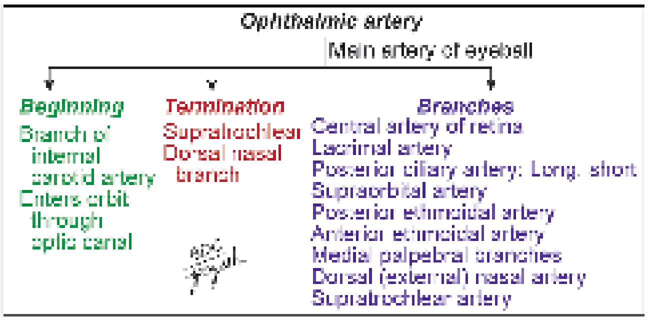


Fig. 13.12: Medial squint of the right eye

Flowchart 13.2: Ophthalmic artery


Ophthalmic artery
Main artery of eyeball
Beginning
Branch of internal carotid artery
Enters orbit through optic canal
Termination
Supratrochlear
Dorsal nasal branch
Branches
Central artery of retina
Lacrimal artery
Posterior ciliary artery: Long, short
Supraorbital artery
Posterior ethmoidal artery
Anterior ethmoidal artery
Medial palpebral branches
Dorsal (external) nasal artery
Supratrochlear artery

2. In the orbit, the artery pierces the dura mater, ascends over the lateral side of the optic nerve, and crosses above the nerve from lateral to medial side along with the nasociliary nerve. It then runs forwards along the medial wall of the orbit between the superior oblique and the medial rectus muscles and parallel to the nasociliary nerve.
3. It terminates near the medial angle of the eye by dividing into the supratrochlear and dorsal nasal branches.

Branches

The ophthalmic artery has the following branches:

1. Central artery of retina
2. Lacrimal artery
    a. Glandular branches to lacrimal gland
    b. Two palpebral branches – one for each eyelid
    c. Two zygomatic branches – zygomaticofacial and zygomaticotemporal
    d. Recurrent meningeal branches
    e. Muscular branches.
3. Posterior (long and short) ciliary arteries
4. Supraorbital artery
5. Posterior ethmoidal artery
6. Anterior ethmoidal artery
7. Medial palpebral branches – one for each eyelid
8. Dorsal (external) nasal artery (terminal branch)
9. Supratrochlear artery (terminal branch).

The distribution of the branches of the ophthalmic artery is given in Table 13.3.

Central Artery of Retina

While still within the dural sheath, the ophthalmic artery gives off the *central artery of the retina*. Figure 13.10 is the first and most important branch of the ophthalmic

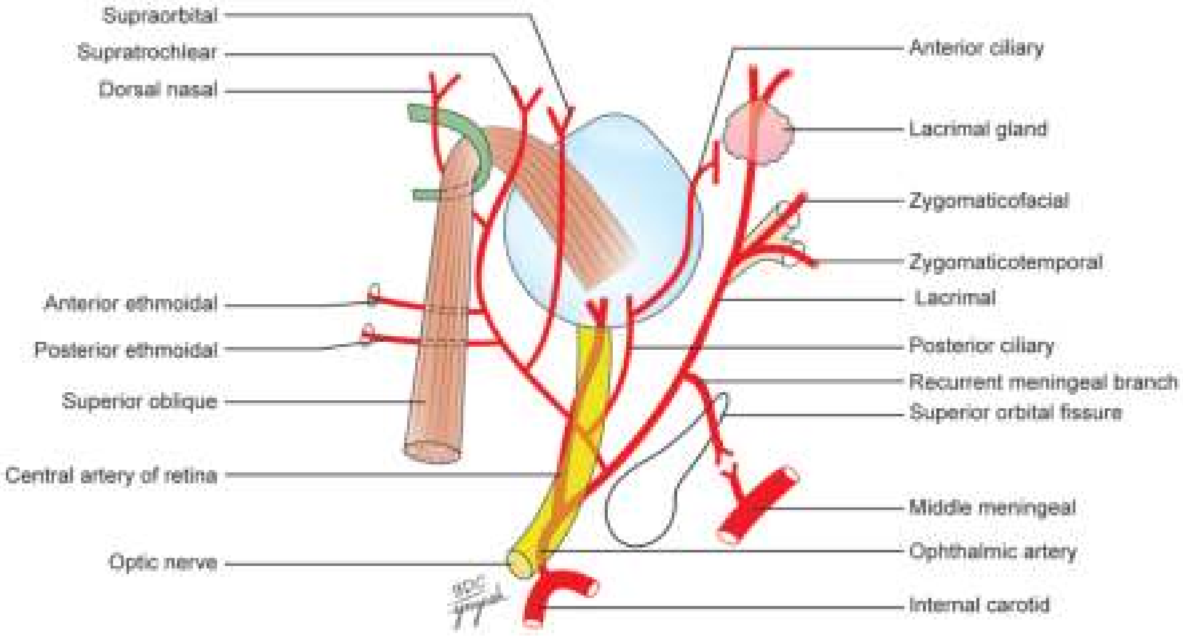

Supraorbital
Supratrochlear
Dorsal nasal
Anterior ethmoidal
Posterior ethmoidal
Superior oblique
Central artery of retina
Optic nerve
Anterior ciliary
Lacrimal gland
Zygomaticofacial
Zygomaticotemporal
Lacrimal
Posterior ciliary
Recurrent meningeal branch
Superior orbital fissure
Middle meningeal
Ophthalmic artery
Internal carotid

Fig. 13.13: Arteries of the eyeball

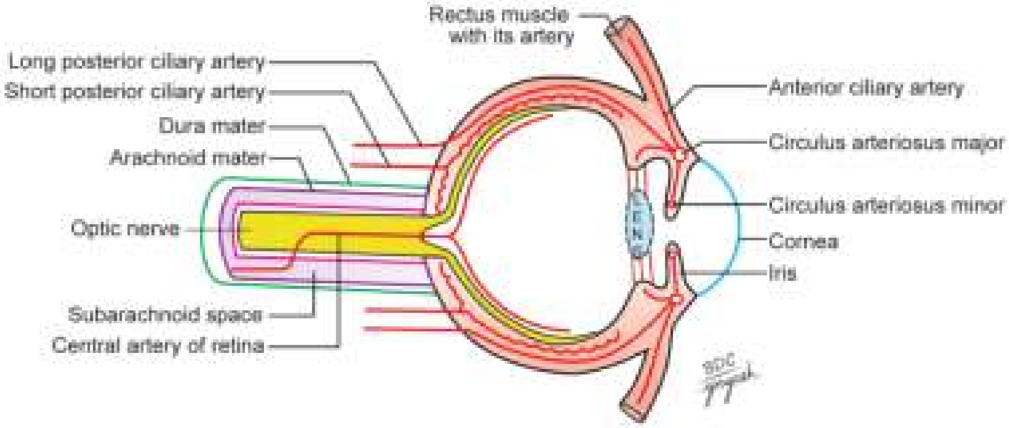

Rectus muscle with its artery
Long posterior ciliary artery
Short posterior ciliary artery
Dura mater
Arachnoid mater
Optic nerve
Subarachnoid space
Central artery of retina
Anterior ciliary artery
Circulus arteriosus major
Circulus arteriosus minor
Cornea
Iris

Fig. 13.14: Branches of ophthalmic artery

TABLE 13.3: Branches of the ophthalmic artery

Branches	***Course and distribution***
Central artery of retina	Supply the retina
Lacrimal artery	
Glandular branches	Lacrimal gland
Two palpebral branches	One for each eyelid
Two zygomatic branches	Enter canals in the zygomatic bone. One branch appears on the face through the zygomaticofacial foramen. The other appears on the temporal surface of the bone through the zygomaticotemporal foramen
Recurrent meningeal branches	Runs backwards to enter the middle cranial fossa through the superior orbital fissure
Muscular branches	Muscles of the orbit
Branches arising from the main trunk	
Posterior (long and short) ciliary arteries	Supply chiefly the choroid and iris
Supraorbital and supratrochlear branches	Supply the skin of the forehead
Anterior and posterior ethmoidal branches	Enter foramina in the medial wall of the orbit to supply the ethmoidal air sinuses. They then enter the anterior cranial fossa. The terminal branches of the anterior ethmoidal artery enter the nose and supply part of it.
Medial palpebral branches	Supply the eyelids
Dorsal nasal branch	Supplies the upper part of the nose

artery. It first lies below the optic nerve. It pierces the dural sheath of the nerve and runs forwards for a short distance between these two. It then enters the substance of the nerve and runs forwards in its centre to reach the optic disc (Fig. 13.9). Here it divides into branches that supply the retina (*see* Fig. 19.6).

CLINICAL ANATOMY

- The anterior ciliary arteries arise from the muscular branches of ophthalmic artery. The muscular arteries are important in this respect.
- The central artery of the retina is an ***end artery***. It does not have effective anastomoses with other arteries. Occlusion of the artery results in ***blindness***. The intraocular part of the artery can be seen, in the living, through an ***ophthalmoscope*** (*see* Fig. 19.12).

DISSECTION

Trace the ophthalmic artery after it was seen to cross over the optic nerve along with nasociliary nerve and superior ophthalmic vein. Identify its branches especially the central artery of the retina which is an 'end artery'.

OPHTHALMIC VEINS

Superior ophthalmic vein: It accompanies the ophthalmic artery. It lies above the optic nerve. It receives tributaries corresponding to the branches of the artery, passes through the superior orbital fissure, and drains into the cavernous sinus. It communicates anteriorly with the supraorbital and angular veins.

Inferior ophthalmic vein: It runs below the optic nerve. It receives tributaries from the lacrimal sac, the lower orbital muscles, and the eyelids, and ends either by joining the superior ophthalmic vein or drains directly into the cavernous sinus. It communicates with the pterygoid plexus of veins by small veins passing through the inferior orbital fissure.

Lymphatics of the Orbit

The lymphatics drain into the preauricular parotid lymph nodes.

Competency:
AN31.2 Describe and demonstrate nerves of the orbit.

NERVES OF THE ORBIT

These are:

1. Optic (II)
2. Ciliary ganglion
3. Oculomotor (III) and trochlear (IV)
4. Abducent (VI)
5. Branches of ophthalmic (V1) and maxillary divisions (V2) of the trigeminal nerve
6. Sympathetic nerves.

OPTIC NERVE

The optic nerve is the nerve of sight. It is made up of the axons of cells in the ganglionic layer of the retina. It emerges from the eyeball 3 or 4 mm nasal to its posterior pole. It runs backwards and medially and passes through the optic canal to enter the middle cranial fossa where it joins the optic chiasma.

The nerve is about 4 cm long, out of which 25 mm are intraorbital, 5 mm intracanalicular, and 10 mm intracranial. The entire nerve is enclosed in three meningeal sheaths. The subarachnoid space extends around the nerve up to the eyeball.

Relations in the Orbit

1. At the apex of the orbit, the nerve is closely surrounded by the recti muscles. The ciliary ganglion lies between the optic nerve and the lateral rectus.
2. The central artery and vein of the retina pierce the optic nerve inferomedially about 1.25 cm behind the eyeball.
3. The optic nerve is crossed superiorly by the ophthalmic artery, the nasociliary nerve and the superior ophthalmic vein.
4. The optic nerve is crossed inferiorly by the nerve to the medial rectus.
5. Near the eyeball, the nerve is surrounded by fat containing the ciliary vessels and nerves.

Structure

1. There are about 1.2 million myelinated fibres in each optic nerve, out of which about 53% cross in the optic chiasma.
2. The optic nerve is not a nerve in the strict sense as there is no neurolemmal sheath. It is actually a tract. It cannot regenerate, if it is cut. Developmentally, the optic nerve and the retina are a direct prolongation of the brain.

Note: Optic nerve has no neurilemmal sheath, and has no power of regeneration. It is a tract and not a nerve.

CLINICAL ANATOMY

- The anastomoses between tributaries of facial vein and ophthalmic veins may result in spread of infection from the orbital and nasal regions to the cavernous sinus leading to its thrombosis.
- ***Optic neuritis*** is characterized by pain in and behind the eye on ocular movements and on pressure. The ***papilloedema*** is less but loss of vision is more. When the optic disc is normal as seen by an ophthalmoscope the same condition is called retrobulbar neuritis. The common causes are demyelinating diseases of the central nervous system, any septic focus in the teeth or paranasal sinuses, meningitis, encephalitis, syphilis, and even vitamin B deficiency.
- Optic atrophy may be caused by a variety of diseases. It may be primary or secondary.

CILIARY GANGLION

The ciliary ganglion is a peripheral parasympathetic ganglion (Fig. 13.15, Flowchart 13.3).

Size: It is about 1–2 mm in diameter (about the size of pin's head).

Neuronal relationship

Topographic relation: It is connected with the nasociliary nerve.

Functional relation: It is functionally related to the oculomotor nerve.

Location

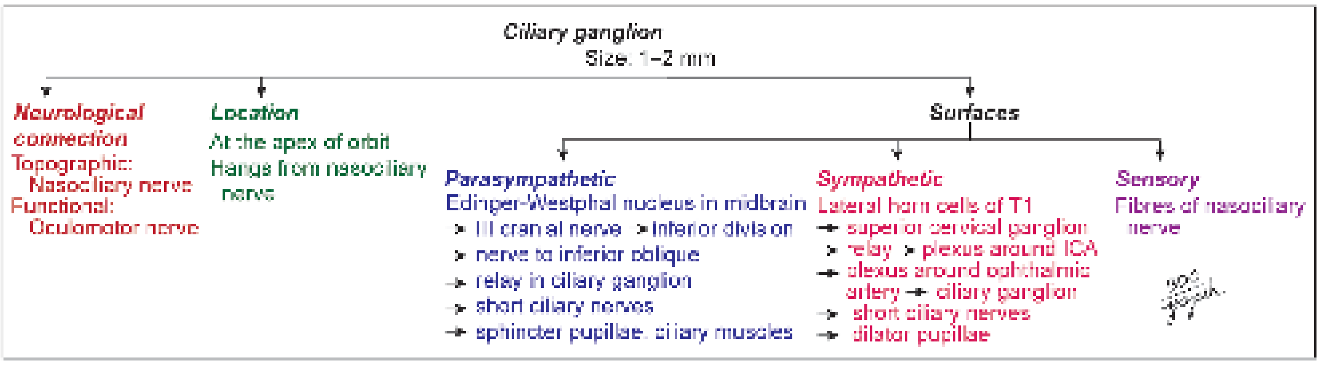
It is situated near the apex of the orbit between the optic nerve and the origin of the lateral rectus muscle. It hangs from the nasociliary nerve. The ganglion lies medial to the ophthalmic artery.

Roots (connections and distribution) (Fig. 13.16)

The ciliary ganglion has three roots:

1. *Parasympathetic* or *secretomotor root*: It consists of pre- and post-ganglionic fibres.
   a. *Preganglionic fibres* begin from the Edinger-Westphal nucleus located in the midbrain at the level of superior colliculus. These fibres pass through the oculomotor nerve and then they branch to the inferior oblique. These fibres relay in the *ciliary ganglion*.
   b. *Postganglionic fibres* from the cells of ciliary ganglion join the *short ciliary nerve* and supply the two intraocular muscles – *sphincter pupillae and ciliary muscles*.
2. *Sympathetic root*: The lateral horn cells of T1 segment of spinal cord give rise to preganglionic sympathetic fibres. They traverse to T1 nerve, sympathetic chain, and relay in superior cervical sympathetic ganglion. Postganglionic fibres pass along the plexus around the internal carotid and then ophthalmic artery. These fibres pass through the ciliary ganglion without relay and join the short ciliary nerves. They supply blood vessels of the eyeball and *dilator pupillae* muscle.
3. *Sensory root*: These are the fibres of *nasociliary nerve*. They pass through the ganglion without relay. They carry general sensation from the eyeball.

Flowchart 13.3: Ciliary ganglion


Ciliary ganglion
Size: 1–2 mm
Neurological connection
Topographic:
Nasociliary nerve
Functional:
Oculomotor nerve
Location
At the apex of orbit
Hangs from nasociliary nerve
Surfaces
Parasympathetic
Edinger-Westphal nucleus in midbrain
→ III cranial nerve → inferior division
→ nerve to inferior oblique
→ relay in ciliary ganglion
→ short ciliary nerves
→ sphincter pupillae, ciliary muscles
Sympathetic
Lateral horn cells of T1
→ superior cervical ganglion
→ relay → plexus around ICA
→ plexus around ophthalmic artery → ciliary ganglion
→ short ciliary nerves
→ dilator pupillae
Sensory
Fibres of nasociliary nerve

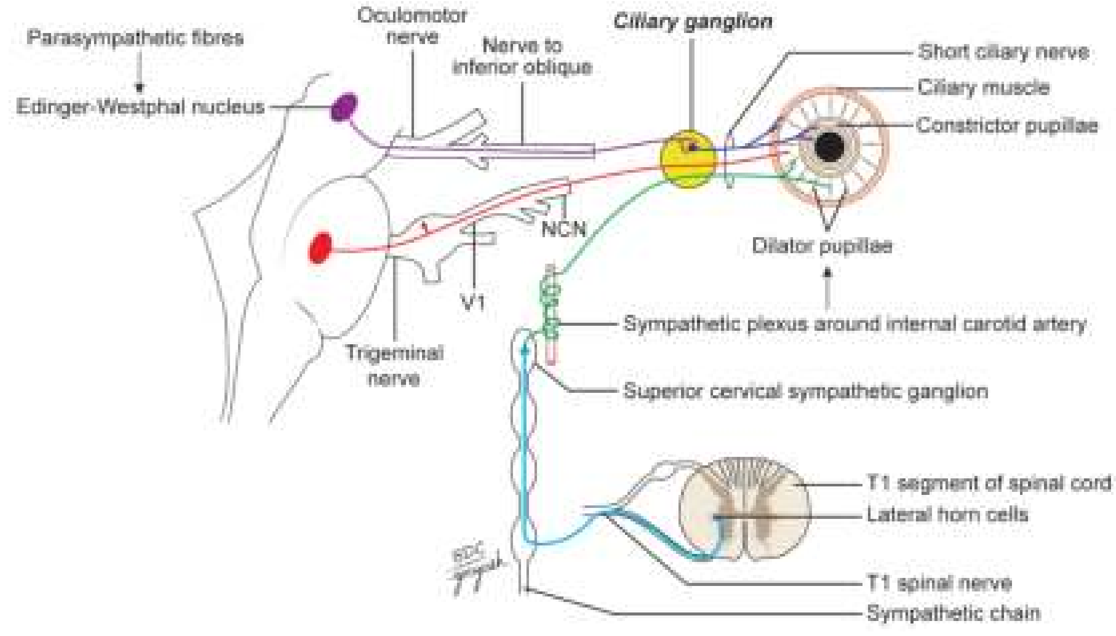

Parasympathetic fibres
Edinger-Westphal nucleus
Oculomotor nerve
Nerve to inferior oblique
Ciliary ganglion
Short ciliary nerve
Ciliary muscle
Constrictor pupillae
NCN
Dilator pupillae
V1
Trigeminal nerve
Sympathetic plexus around internal carotid artery
Superior cervical sympathetic ganglion
T1 segment of spinal cord
Lateral horn cells
T1 spinal nerve
Sympathetic chain

Fig. 13.15: Ciliary ganglion (V1: Ophthalmic nerve, NCN: Nasociliary nerve)

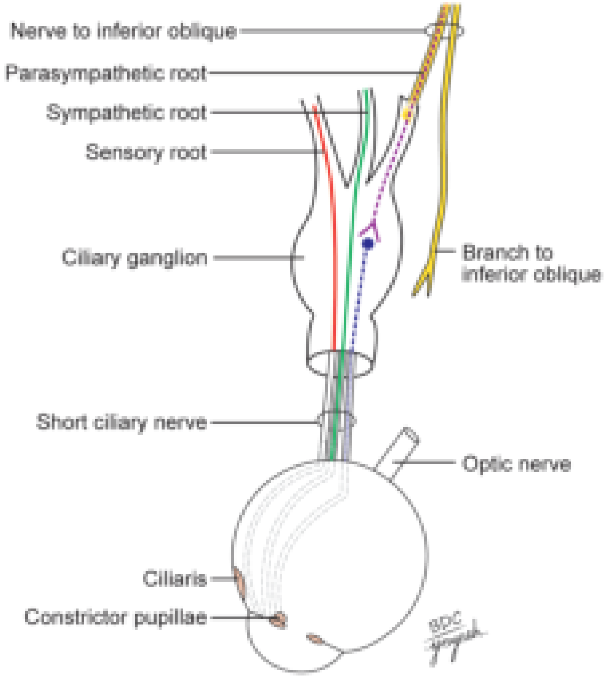

Nerve to inferior oblique
Parasympathetic root
Sympathetic root
Sensory root
Ciliary ganglion
Branch to inferior oblique
Short ciliary nerve
Optic nerve
Ciliaris
Constrictor pupillae

Fig. 13.16: Roots and branches of ciliary ganglion

Functions/branches

The ciliary ganglion gives off 8–10 short ciliary nerves which divides into 15–20 branches. These small branches pierce the sclera around the entrance of the optic nerve. These fibres from ciliary ganglion perform the following functions:

1. Parasympathetic fibres – motor to sphincter pupillae and ciliary muscle.
2. Sympathetic fibres – vasomotor to vessels and motor to dilator pupillae muscle.
3. Sensory fibres carry general sensation from the eyeball.

Ciliary nerve block: It produces dilatation of pupil before cataract surgery.

OCULOMOTOR NERVE

Course of oculomotor (III) nerve is shown by Flowchart 13.4.

TROCHLEAR NERVE

Course of trochlear (IV) nerve is shown by Flowchart 13.5 and Fig. 13.17.

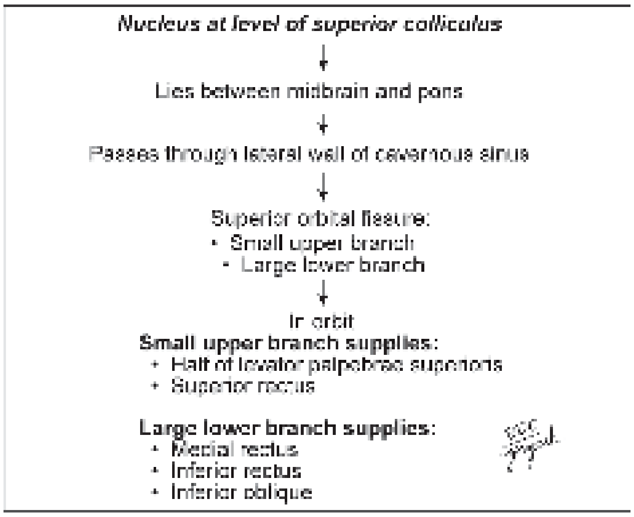
ABDUCENT NERVE

Course of abducent (VI) nerve is depicted by Flowchart 13.6, Figs 13.18 and 13.9 (details can be read from Chapter 6, *BD Chaurasia's Human Anatomy*, *Volume 4*).

BRANCHES OF OPHTHALMIC DIVISION OF TRIGEMINAL NERVE

The ophthalmic (V1) is the smallest branch of trigeminal nerve (others are maxillary and mandibular nerves) (Flowchart 13.7).

Flowchart 13.4: Oculomotor nerve—III nerve



Nucleus at level of superior colliculus

↓

Lies between midbrain and pons

↓

Passes through lateral wall of cavernous sinus

↓

Superior orbital fissure:
- Small upper branch
- Large lower branch

↓

In orbit

Small upper branch supplies:
- Half of levator palpebrae superioris
- Superior rectus

Large lower branch supplies:
- Medial rectus
- Inferior rectus
- Inferior oblique

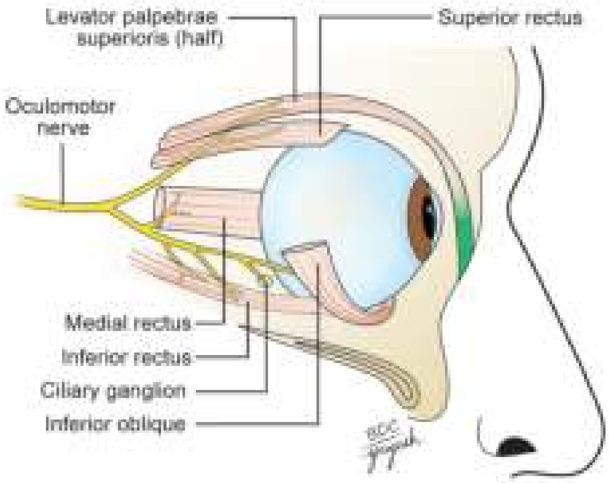
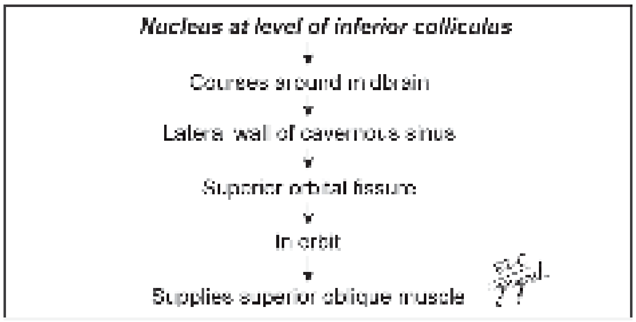

Levator palpebrae superioris (half)
Superior rectus
Oculomotor nerve
Medial rectus
Inferior rectus
Ciliary ganglion
Inferior oblique

Fig. 13.17: Distribution of oculomotor nerve

Flowchart 13.5: Trochlear—IV nerve



Nucleus at level of inferior colliculus

↓

Courses around midbrain

↓

Lateral wall of cavernous sinus

↓

Superior orbital fissure

↓

In orbit

↓

Supplies superior oblique muscle

The ophthalmic nerve is purely sensory nerve. It arises from the anterolateral aspect of trigeminal ganglion in the middle cranial fossa. Then the nerve enters the lateral wall of the cavernous sinus and runs forward below the trochlear nerve and above the maxillary nerve. In the lateral wall of cavernous sinus, the ophthalmic nerve divides into three terminal branches: Lacrimal, frontal, and nasociliary (*mnemonic*: LFN). All the branches enter the orbit through the superior orbital fissure.

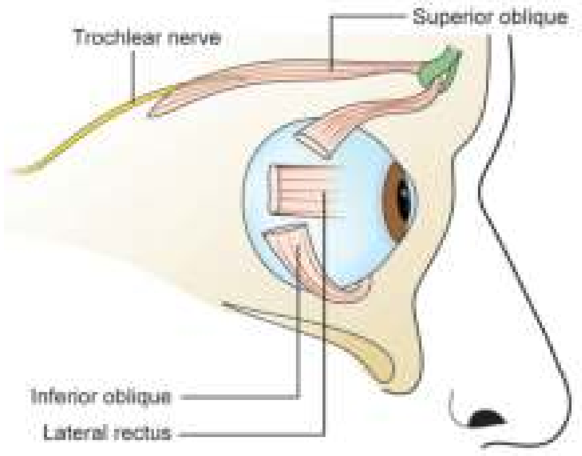
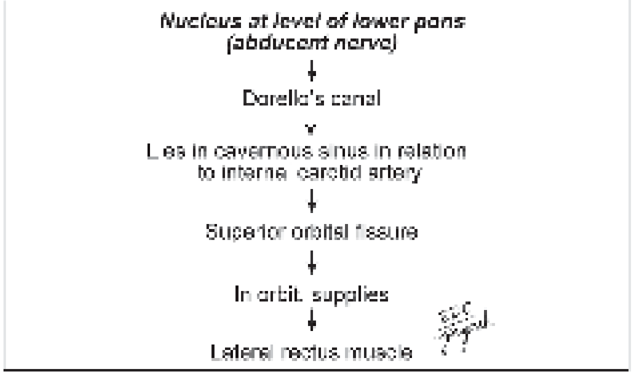

Superior oblique
Trochlear nerve
Inferior oblique
Lateral rectus

Fig. 13.18: Course of trochlear nerve

Flowchart 13.6: Abducent nerve—VI nerve


Nucleus at level of lower pons (abducent nerve)
Dorello's canal
Lies in cavernous sinus in relation to internal carotid artery
Superior orbital fissure
In orbit, supplies
Lateral rectus muscle

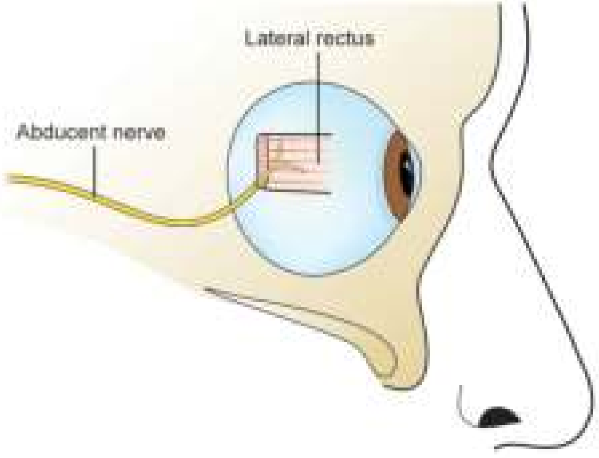

Lateral rectus
Abducent nerve

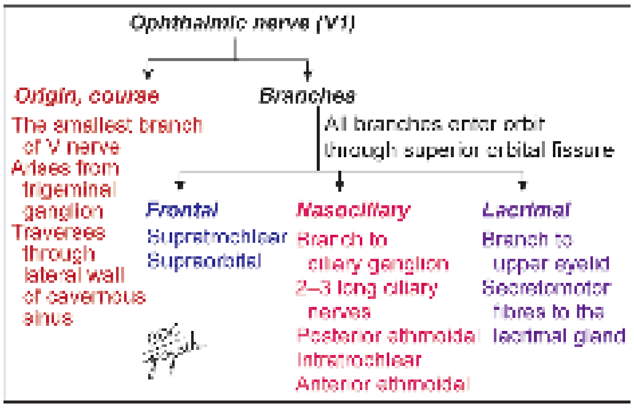
Fig. 13.19: Distribution of abducent nerve

Branches

Following are the branches of ophthalmic division of trigeminal nerve (Figs 13.20a and b).

1. Frontal nerve:
   a. Supratrochlear
   b. Supraorbital.
2. Nasociliary nerve:
   a. Branch to ciliary ganglion
   b. 2–3 long ciliary nerves

Flowchart 13.7: Ophthalmic nerve (V1)


Ophthalmic nerve (V1)
Origin, course
The smallest branch of V nerve
Arises from trigeminal ganglion
Traverses through lateral wall of cavernous sinus
Branches
All branches enter orbit through superior orbital fissure
Frontal
Supratrochlear
Supraorbital
Nasociliary
Branch to ciliary ganglion
2–3 long ciliary nerves
Posterior ethmoidal
Intratrochlear
Anterior ethmoidal
Lacrimal
Branch to upper eyelid
Secretomotor fibres to the lacrimal gland

   c. Posterior ethmoidal
   d. Intratrochlear
   e. Anterior ethmoidal.
3. Lacrimal:
   a. Branch to upper eyelid
   b. Secretomotor fibres to the lacrimal gland.

Lacrimal Nerve

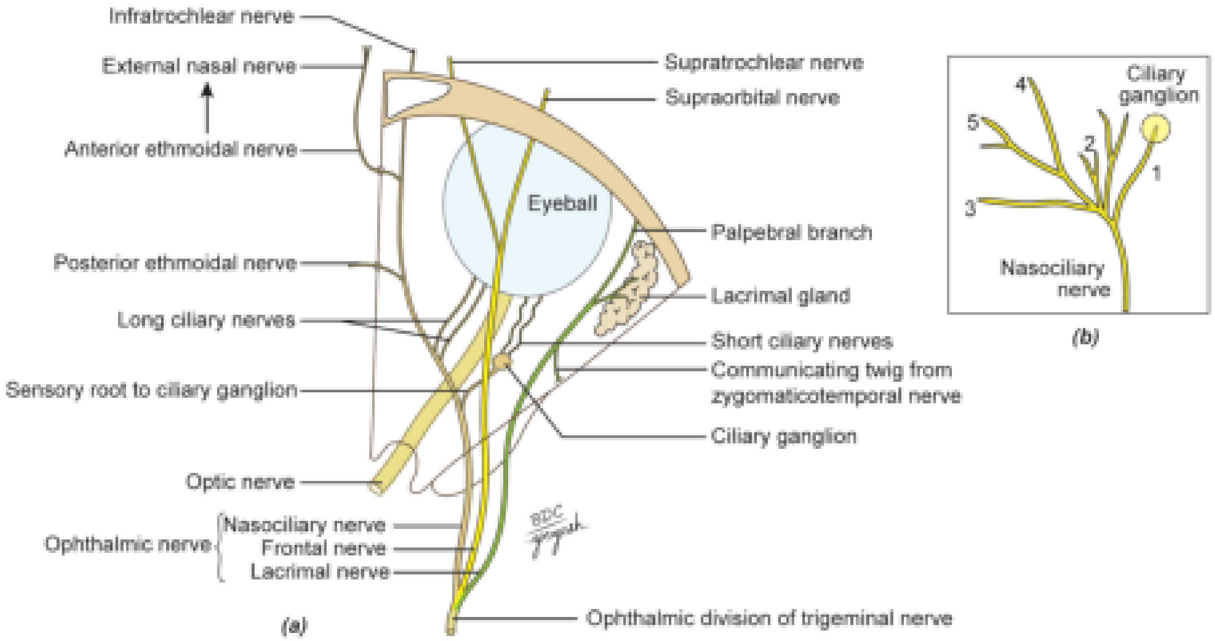
This is the smallest of the three terminal branches of ophthalmic nerve (Fig. 13.15a). It enters the orbit through lateral part of superior orbital fissure and runs forwards along the upper border of lateral rectus muscle, in company with lacrimal artery. Anteriorly, it receives communication from zygomaticotemporal nerve, passes deep to the lacrimal gland, and ends in the lateral part of the upper eyelid.

The lacrimal nerve supplies the lacrimal gland, the conjunctiva and the upper eyelid. Its own fibres to the gland are sensory. The secretomotor fibres to the gland come from the greater petrosal nerve through its communication with the zygomaticotemporal nerve.

Frontal Nerve

This is the largest of the three terminal branches of the ophthalmic nerve. It begins in the lateral wall of the anterior part of the cavernous sinus. It enters the orbit through the lateral part of the superior orbital fissure, and runs forwards on the superior surface of the levator palpebrae superioris. At the middle of the orbit, it divides into a small supratrochlear branch and a large supraorbital branch.

1. The ***supratrochlear nerve*** emerges from the orbit above the trochlea about one finger breadth from the median plane. It supplies the conjunctiva, the upper eyelid, and a small area of the skin of the forehead above the root of the nose.
2. The ***supraorbital nerve*** emerges from the orbit through the supraorbital notch or foramen about two fingers breadth from the median plane. It divides into medial and lateral branches which runs upwards over the forehead and scalp. It supplies the conjunctiva, the central part of the upper eyelid, the *frontal air sinus* and the skin of the forehead and scalp up to the vertex, or even up to the lambdoid suture.



Infratrochlear nerve
External nasal nerve
Anterior ethmoidal nerve
Posterior ethmoidal nerve
Long ciliary nerves
Sensory root to ciliary ganglion
Optic nerve
Ophthalmic nerve
Nasociliary nerve
Frontal nerve
Lacrimal nerve
(a)
Supratrochlear nerve
Supraorbital nerve
Eyeball
Palpebral branch
Lacrimal gland
Short ciliary nerves
Communicating twig from zygomaticotemporal nerve
Ciliary ganglion
Ophthalmic division of trigeminal nerve
4
5
3
2
1
Ciliary ganglion
Nasociliary nerve
(b)

Figs 13.20a and b: (a) Branches of right ophthalmic nerve including III, IV, VI cranial nerves and the extraocular muscles and (b) branches of nasociliary: (1) Branch to ciliary ganglion; (2) Long ciliary; (3) Posterior ethmoidal; (4) Infratrochlear; (5) Anterior ethmoidal

Nasociliary Nerve

This is one of the terminal branches of the ophthalmic division of the trigeminal nerve. It begins in the lateral wall of the anterior part of the cavernous sinus. It enters the orbit through the middle part of the superior orbital fissure between the two divisions of the oculomotor nerve. It crosses above the optic nerve from lateral to medial side along with ophthalmic artery and runs along the medial wall of the orbit between the superior oblique and the medial rectus. It ends at the anterior ethmoidal foramen by dividing into the infratrochlear and anterior ethmoidal nerves. Its branches are as follows:

1. A *communicating branch to the ciliary ganglion* forms the sensory root of the ganglion. It is often mixed with the sympathetic root.
2. Two or three ***long ciliary nerves*** run on the medial side of the optic nerve, pierce the sclera, and supply sensory nerves to the cornea, the iris and the ciliary body. They also carry sympathetic nerves to the dilator pupillae.
3. The ***posterior ethmoidal nerve*** passes through the posterior ethmoidal foramen and supplies the ethmoidal and sphenoidal air sinuses.
4. The ***infratrochlear nerve*** is the smaller terminal branch of the nasociliary nerve given off at the anterior ethmoidal foramen. It emerges from the orbit below the trochlea for the tendon of the superior oblique and appears on the face above the medial angle of the eye. It supplies the conjunctiva, the lacrimal sac and caruncle, the medial ends of the eyelids and the upper half of the external nose.
5. The ***anterior ethmoidal nerve*** is the larger terminal branch of the nasociliary nerve. It leaves the orbit by passing through the anterior ethmoidal foramen. It appears, for a very short distance, in the anterior cranial fossa, above the cribriform plate of the ethmoid bone. It then descends into the nose through a slit at the side of the anterior part of the crista galli. In the nasal cavity, it lies deep to the nasal bone. It gives off two ***internal nasal branches***—medial and lateral to the mucosa of the nose. Finally, it emerges at the lower border of the nasal bone as the ***external nasal nerve*** which supplies the skin of the lower half of the nose.

SOME BRANCHES OF MAXILLARY DIVISION OF THE TRIGEMINAL NERVE

Infraorbital Nerve (Fig. 13.21)

It is the continuation of the maxillary nerve. It enters the orbit through the *inferior orbital fissure*. It then runs forwards on the floor of the orbit or the roof of the maxillary sinus, at first in the *infraorbital groove* and then in the *infraorbital canal* remaining outside the periosteum of the orbit. It emerges on the face through the *infraorbital foramen* and terminates by dividing into palpebral, nasal and labial branches. The nerve is accompanied by the infraorbital branch of the third part of the maxillary artery and the accompanying vein.

Branches

1. ***Middle superior alveolar nerve*** arises in the infraorbital groove, runs in the lateral wall of the maxillary sinus, and supplies the upper premolar teeth.
2. ***Anterior superior alveolar nerve*** arises in the infraorbital canal, and runs in a sinuous canal having a complicated course in the anterior wall of the maxillary sinus. It supplies the upper incisor and canine teeth, the maxillary sinus, and the anteroinferior part of the nasal cavity where it communicates with branches of anterior ethmoidal and anterior palatine nerves.

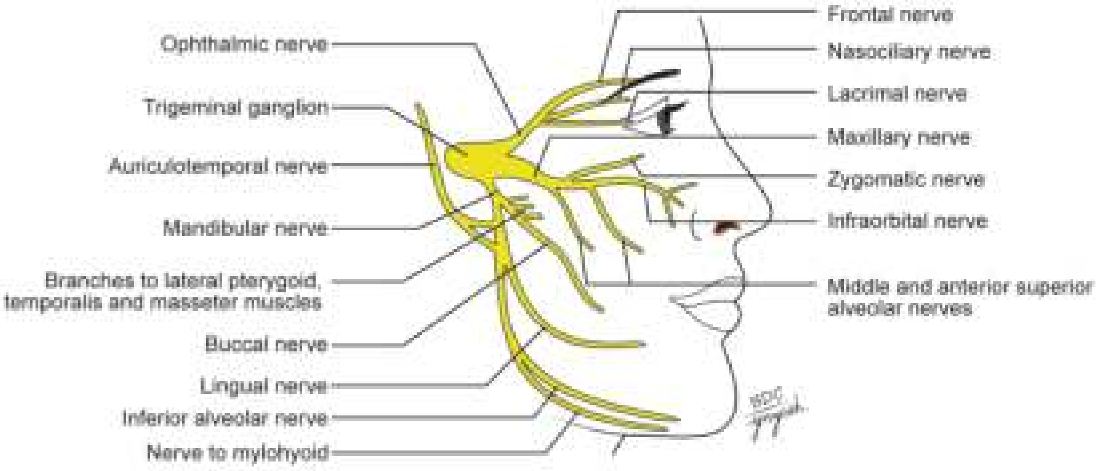

Ophthalmic nerve
Trigeminal ganglion
Auriculotemporal nerve
Mandibular nerve
Branches to lateral pterygoid, temporalis and masseter muscles
Buccal nerve
Lingual nerve
Inferior alveolar nerve
Nerve to mylohyoid
Frontal nerve
Nasociliary nerve
Lacrimal nerve
Maxillary nerve
Zygomatic nerve
Infraorbital nerve
Middle and anterior superior alveolar nerves
BDC

Fig. 13.21: Some branches of ophthalmic, maxillary and mandibular branches of trigeminal nerve

3. *Terminal branches*—***palpebral, nasal and labial***—supply a large area of skin on the face. They also supply the mucous membrane of the upper lip and cheek.

Zygomatic Nerve

It is a branch of the maxillary nerve, given off in the pterygopalatine fossa. It enters the orbit through the lateral end of the inferior orbital fissure, and runs along the lateral wall, outside the periosteum, to enter the zygomatic bone. Just before or after entering the bone, it divides into its two terminal branches, the *zygomaticofacial* and *zygomaticotemporal nerves* which supply the skin of the face and of the anterior part of the temple. The communicating branch to the lacrimal nerve, which contains secretomotor fibres to the lacrimal gland, arises from the zygomaticotemporal nerve, and runs in the lateral wall of the orbit. Detailed description is given in *see* Chapter 15.

SYMPATHETIC NERVES OF THE ORBIT

Sympathetic nerves arise from the internal carotid plexus and enter the orbit through the following sources.

1. The dilator pupillae of the iris is supplied by sympathetic nerves that pass through the ophthalmic nerve, the nasociliary nerve, and its long ciliary branches.
2. Other sympathetic nerves enter the orbit as follows:
   a. A plexus surrounds the ophthalmic artery.
   b. A direct branch from the internal carotid plexus passes through the superior orbital fissure and joins the ciliary ganglion.
   c. Other filaments pass along the oculomotor, trochlear, abducent, and ophthalmic nerves. All these sympathetic nerves are vasomotor in function.

VIDEO

Video 3.13 **Orbit**

Facts to Remember

- Levator palpebrae superioris is partly supplied by III nerve and partly by sympathetic fibres.
- Central artery of retina is an end artery.
- Nerve supply of extraocular muscles is LR6, SO4, rest (levator palpebrae superioris, SR, MR, IR and IO) by III.
- Edinger-Westphal is the nucleus for the supply of ciliaris muscles and constrictor pupillae muscles. The fibres supply these muscles after relaying in the ciliary ganglion.
- Elevation and depression of the cornea occur around a transverse axis.
- Adduction and abduction of the cornea take place around a vertical axis.
- Intorsion and extorsion occur around an anteroposterior axis.

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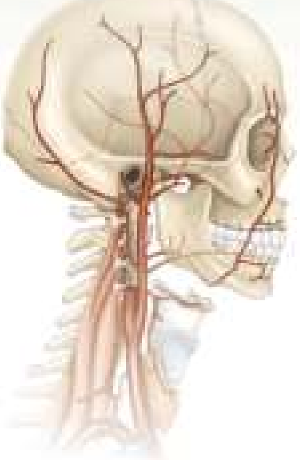
1. Actions of individual muscles according to their axes
2. Actions of individual muscles according to the position of eye
3. Single or pure movements of the eyeball
4. Further reading
5. Viva voce questions



Chapter 14

Mouth and Pharynx

ORAL CAVITY

Oral cavity is used for ingestion of food and fluids. It is continued posteriorly into the oropharynx, the middle part of the muscular pharynx. In its upper part, opens the posterior part of the nasal cavity and the inlet of larynx opens into its lower part. Roof of oral cavity is formed by the hard and the soft palates. Tongue is the biggest occupant of the oral cavity, described in Chapter 17. The cavity also contains 32 teeth in an adult.

Divisions

The oral or mouth cavity is divided into:

1. An outer, smaller portion – vestibule
2. An inner larger part – oral cavity proper.

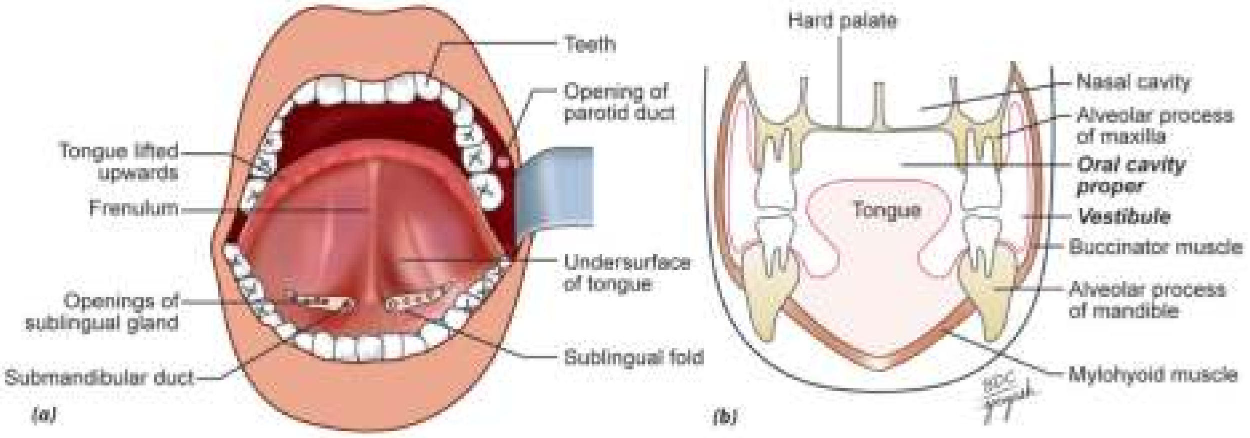
Competency:
AN36.1 Describe and demonstrate the structures of the vestibule of the mouth and oral cavity proper.

VESTIBULE

1. The vestibule of the mouth is a narrow space *bounded* externally by the lips and cheeks, and internally by the teeth and gums (Figs 14.1a and b).
2. It *communicates*:
   a. With the exterior through the oral fissure.
   b. With the mouth open, it communicates freely with the oral cavity proper. Even when the teeth are occluded a small communication remains behind the third molar tooth.
3. The ***parotid duct*** opens on the inner surface of the cheek opposite the crown of the upper second molar tooth. Numerous ***labial and buccal glands*** (mucous) situated in the submucosa of the lips and cheeks open into the vestibule. Four or five ***molar glands*** (mucous), situated on the buccopharyngeal fascia, also open into the vestibule.
4. Except for the teeth, the entire vestibule is lined by mucous membrane. The mucous membrane forms median folds that pass from the lips to the gums, and are called the ***frenula of the lips***.

CLINICAL ANATOMY

- The ***papilla of the parotid duct*** in the vestibule of the mouth provides access to the parotid duct for the injection of the radio-opaque dye to locate calculi in the duct system or the gland.
- ***Koplik's spots*** are seen as white pinpoint spots around the opening of the parotid duct in measles. These are diagnostic of the disease.


Teeth
Opening of parotid duct
Tongue lifted upwards
Frenulum
Undersurface of tongue
Openings of sublingual gland
Sublingual fold
Submandibular duct
(a)
Hard palate
Nasal cavity
Alveolar process of maxilla
Oral cavity proper
Tongue
Vestibule
Buccinator muscle
Alveolar process of mandible
Mylohyoid muscle
(b)

Figs 14.1a and b: (a) Interior of the mouth cavity and (b) subdivisions of the oral cavity in coronal section

LIPS

1. The lips are fleshy folds lined externally by skin and internally by mucous membrane. The ***mucocutaneous junction*** lines the 'edge' of the lip, part of the mucosal surface is also normally seen.
2. ***Layers*: **Each lip is *composed* of:
   a. Skin
   b. Superficial fascia
   c. The orbicularis oris muscle
   d. The submucosa, containing mucous labial glands and blood vessels
   e. Mucous membrane.
3. The lips bound the ***oral fissure***. They meet laterally at the angles of the mouth. The inner surface of each lip is supported by a ***frenulum*** which ties it to the gum. Philtrum is a median vertical groove on the outer surface of the upper lip.
4. *Lymphatics* of the central part of the lower lip drain to the submental nodes; the lymphatics from the rest of the lower lip pass to the submandibular nodes.

Note: ***Vermilion*** or ***red margin*** is a mucocutaneous junction. The free margin of the lip shows vermilion. Large number of the blood vessels that are present beneath the epithelium gives red colour to the lip.

CHEEKS (BUCCAE)

1. The cheeks are fleshy flaps, forming a large part of each side of the face. They are continuous in front with the lips, and the junction is indicated by the *nasolabial sulcus* (*furrow*) which extends from the side of the nose to the angle of the mouth.
2. ***Layers*: **Each cheek is *composed of:*
   a. Skin
   b. Superficial fascia containing some facial muscles, the parotid duct, mucous molar glands, vessels and nerves.
   c. The buccinator covered by buccopharyngeal fascia and pierced by the parotid duct.
   d. Submucosa, with mucous buccal glands.
   e. Mucous membrane.
3. The *buccal pad of fat* is best developed in infants. It lies on the buccinator partly deep to the masseter and partly in front of it.
4. The *lymphatics* of the cheek drain chiefly into the submandibular and preauricular nodes, and partly also to the buccal and mandibular nodes.

ORAL CAVITY PROPER

1. Boundaries:
   Anterolaterally – Teeth, the gums and the alveolar arches of the jaws.
   Roof – Formed by the hard palate and the soft palate.
   Floor – Occupied by the tongue posteriorly, and presents the sublingual region anteriorly, below the tip of the tongue.
   Posteriorly – The cavity communicates with the pharynx through the ***oropharyngeal isthmus*** *(isthmus of fauces)* which is bounded superiorly by the soft palate, inferiorly by the tongue, and on each side by the palatoglossal arches.
2. The ***sublingual region*** presents the following features:
   a. In the median plane, there is a fold of mucosa passing from the inferior aspect of the tongue to the floor of the mouth. This is the *frenulum* of the tongue.
   b. On each side of the frenulum, there is a ***sublingual papilla***. On the summit of this papilla, there is the opening of submandibular duct.
   c. Running laterally and backwards from the sublingual papilla, there is the ***sublingual fold*** which overlies the sublingual gland. A few sublingual ducts open on the edge of this fold.
3. *Lymphatics* from the anterior part of the floor of the mouth pass to the submental nodes. Those from the hard palate and soft palate pass to the retropharyngeal and upper deep cervical nodes. The gums and the rest of the floor drain into the submandibular nodes.

Gums (Gingivae)

1. The gums are the soft tissues which envelop the alveolar processes of the upper and lower jaws and surround the necks of the teeth. These are composed of dense fibrous tissue covered by stratified squamous epithelium.
2. Each gum has two parts:
   a. The free part surrounds the neck of the tooth like a collar.
   b. The *attached part* is firmly fixed to the alveolar arch of the jaw. The fibrous tissue of the gum is continuous with the periosteum lining the alveoli (periodontal membrane).
3. Nerve supply of gums is shown in Table 14.1.
4. *Lymphatics* of the upper gums pass to the submandibular nodes. The anterior part of the lower gums drains into the submental nodes, whereas the posterior part drains into the submandibular nodes.

CLINICAL ANATOMY

- ***Ludwig's angina*** is the cellulitis of the floor of the mouth. The tongue is forced upwards leading to swelling both below the chin and within the mouth. The disease is usually caused due to a caries molar tooth.
- ***Gingivitis*** is an inflammation of the gums. Its commonest cause is an improper oral hygiene. If it remains untreated, it usually results in tooth loss. It can be identified as swollen red gums, tenderness of gum, pus, or ulceration of gums.
- ***Pyorrhea*** or ***periodontitis*** is an inflammatory condition affecting tissue surrounding the teeth. It has a clinical presentation of pus discharge at the margins of gums and foul-smelling breath.
- In ***scurvy*** (caused by a deficiency of vitamin C), the gums are swollen and spongy, and bleed on touch. In gingivitis, the edges of the gums are red and bleed easily.

TABLE 14.1: Nerve supply of gums

Upper gums	*Nerve supply*
Labial side	Posterior, middle and anterior superior alveolar nerves (V2)
Lingual side	Anterior palatine and nasopalatine nerves (from pterygopalatine ganglion)
Lower gums	
Labial side	Buccal branch of mandibular and incisive branch of mental nerve (V3)
Lingual side	Lingual nerve (V3)

TEETH

The teeth form part of the masticatory apparatus and are fixed to the jaws. In man, the teeth are replaced only once *(diphyodont)* in contrast with nonmammalian vertebrates where teeth are constantly replaced throughout life (*polyphyodont*). The teeth of the first set (dentition) are known as *milk*, or *deciduous teeth*, and the second set, as *permanent teeth*.

Number of Teeth (Figs 14.2a and b)

The ***deciduous teeth*** are 20 in number. In each half of each jaw, there are two incisors, one canine, and two molars.

The ***permanent teeth*** are 32 in number, and consist of two incisors (Latin *to cut*), one canine (Latin *dog*), two premolars (Latin *millstone*), and three molars in each half of each jaw.

Parts of a Tooth

Each tooth has three parts:

1. *Crown*, projecting above or below the gum.
2. *Root*, embedded in the jaw beneath the gum.
3. *Neck*, between the crown and root and surrounded by the gum (Fig. 14.3).

Structure

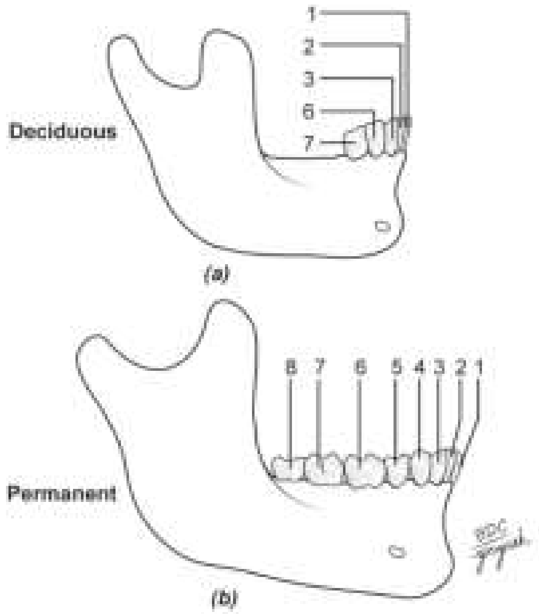
Structurally, each tooth is composed of (Fig. 14.3):

1. Pulp in the centre
2. Dentine surrounding the pulp.
3. Enamel covering the projecting part of dentine, or crown.
4. Cementum surrounding the embedded part of the dentine.
5. Periodontal membrane.

The ***pulp*** is loose fibrous tissue containing vessels, nerves and lymphatics, all of which enter the pulp cavity through the apical foramen. The pulp is covered by a layer of tall columnar cells, known as *odontoblasts* which are capable of replacing dentine any time in life.

The ***dentine*** is a calcified material containing spiral tubules radiating from the pulp cavity. Each tubule is occupied by a protoplasmic process from one of the odontoblasts. The calcium and organic matter are in the same proportion as in bone.

The ***enamel*** is the hardest substance in the body. It is made up of crystalline prisms lying roughly at right angles to the surface of the tooth.



Figs 14.2a and b: Deciduous and permanent teeth: (1) Central incisor; (2) Lateral incisor; (3) Canine; (4) 1st premolar; (5) 2nd premolar; (6) 1st molar; (7) 2nd molar; (8) 3rd molar

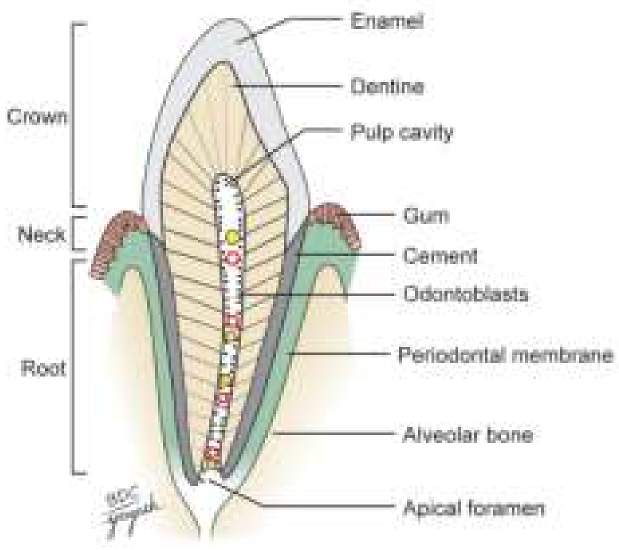


Fig. 14.3: Parts of a tooth

The ***cementum*** resembles bone in structure, but like enamel and dentine, there is neither any blood supply nor any nerve supply. Over the neck, the cementum commonly overlaps the cervical end of enamel; or, less commonly, it may just meet the enamel. Rarely, it stops short of the enamel (10%) leaving the cervical dentine covered only by gum.

The ***periodontal membrane*** *(ligament)* holds the root in its socket. This membrane acts as a periosteum to both the cementum as well as the bony socket.

Form and Function (Crowns and Roots)

1. The shape of a tooth is adapted to its function. The *incisors are cutting teeth,* with chisel-like crowns. The upper and lower incisors overlap each other like the blades of a pair of scissors. *The canines are holding and*

tearing teeth, with conical and rugged crowns. These are better developed in carnivores. Each *premolar* has two cusps and is, therefore, also called a *bicuspid* tooth. The *molars are grinding teeth*, with square crowns, bearing four or five cusps on their crowns.

2. The incisors, canines and premolars have single roots, with the exception of the first upper premolar which has a bifid root. The upper molars have three roots, of which two are lateral and one is medial. The lower molars have only two roots—an anterior and a posterior.

Eruption of Teeth

The *deciduous teeth* begin to erupt at about the 6th month, and all get erupted by the end of the 2nd year or soon after. The teeth of the lower jaw erupt slightly earlier than those of the upper jaw. The approximate ages of eruption of deciduous and permanent teeth are given in Table 14.2.

TABLE 14.2: Usual time of eruption of teeth and time of shedding of deciduous teeth

Tooth	*Eruption time*
Deciduous (Fig. 14.2a)	
Central incisor	6–9 months
Lateral incisor	8–10 months
First molar	12–20 months
Canine	16–20 months
Second molar	20–39 months
Permanent (Fig. 14.2b)	
First molar	6–7 years
Central incisor	7–8 years
Lateral incisor	8–9 years
First premolar	10–11 years
Second premolar	11–12 years
Canine	12–13 years
Second molar	12–14 years
Third molar	18–25 years

Note: The teeth of the lower jaw erupt slightly earlier than those of the upper jaw.

Blood Supply of Teeth

Both upper and lower are supplied by branches of maxillary artery.

Nerve Supply of Teeth

The pulp and periodontal membrane have the same nerve supply which is as follows:

1. *Upper teeth* are supplied by the posterior superior alveolar, middle superior alveolar, and the anterior superior alveolar nerves (maxillary nerve).
2. *Lower teeth* are supplied by the inferior alveolar nerve (mandibular nerve) (Fig. 14.4).

CLINICAL ANATOMY

- Being the hardest and chemically the most stable tissues in the body, the teeth are selectively preserved after death and may be fossilized. Because of this, the teeth are very helpful in medicolegal practice for identification of otherwise unrecognizable dead bodies. The teeth also provide by far the best data to study evolutionary changes and the relationship between ontogeny and phylogeny.
- Decalcification of enamel and dentine with consequent softening and gradual destruction of the tooth is known as ***dental caries***. A caries tooth is tender on mastication.
- Infection of apex of root (apical abscess) occurs only when the pulp is dead. The condition can be recognized in a good radiograph.
- Irregular dentition is common in rickets and the upper permanent incisors may be notched, the notching corresponds to a small segment of a large circle. Even in congenital syphilis, the same teeth are notched, but the notching corresponds to a large segment of a small circle (*Hutchinson's teeth*).
- The third molar teeth, also called ***wisdom teeth***, usually erupt between 18 and 20 years. These may not erupt normally due to less space and may get ***impacted*** causing enormous pain.
- Time of eruption of the teeth helps in assessing the age of the person.
- The upper canine teeth are called as the 'eye teeth' as these have long roots which reach up to the medial angle of the eye. Infection of these roots may spread in the facial vein and even lead to thrombosis of the cavernous sinus.
- The upper teeth need separate injections of the anaesthetic on both the buccal and palatal surfaces of the maxillary process just distal to the tooth. The thin layer of bone permits rapid diffusion of the drug up to the tooth.

Types of Teeth

The humans have *heterodont teeth*, i.e. the teeth are of different types. According to the structure, the teeth are classified as incisors, canines, premolars, and molars (Figs 14.5a and b).

Incisors

These are chisel-like teeth (incisor = to cut in Latin) used to cut the food. There are total eight incisors, four in upper jaw and four are in lower jaw. There are two incisors in each quadrant (out of 4 quadrants) and they are named as follows:

1. Maxillary central incisor
2. Maxillary lateral incisor
3. Mandibular central incisor
4. Mandibular lateral incisor.

In children, incisors erupt as deciduous teeth that later get replaced by permanent teeth. The mandibular central incisor erupts first followed by maxillary central incisors, mandibular lateral incisors, and finally maxillary lateral incisors. Each incisor has five surfaces: Labial, lingual, mesial (medial), distal (lateral), and biting or incisal surfaces. Maxillary incisors are present in premaxillary

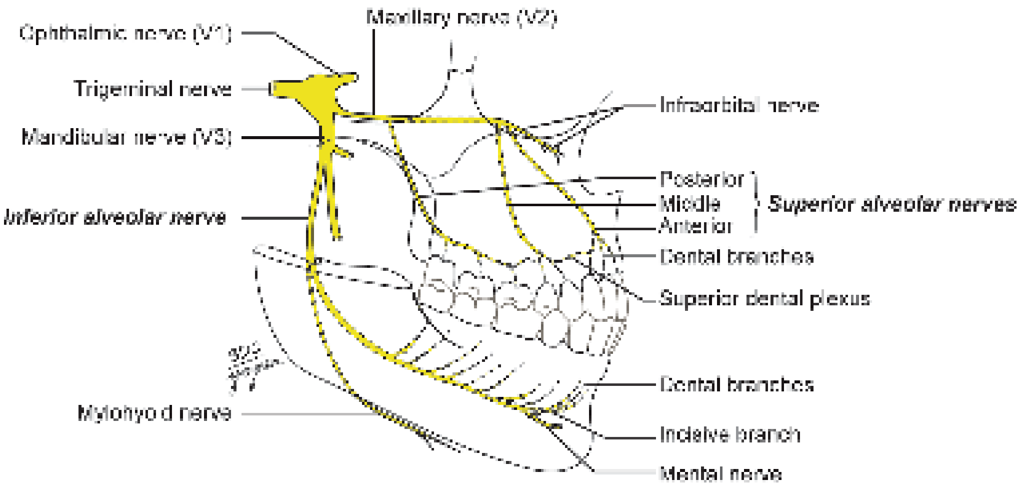
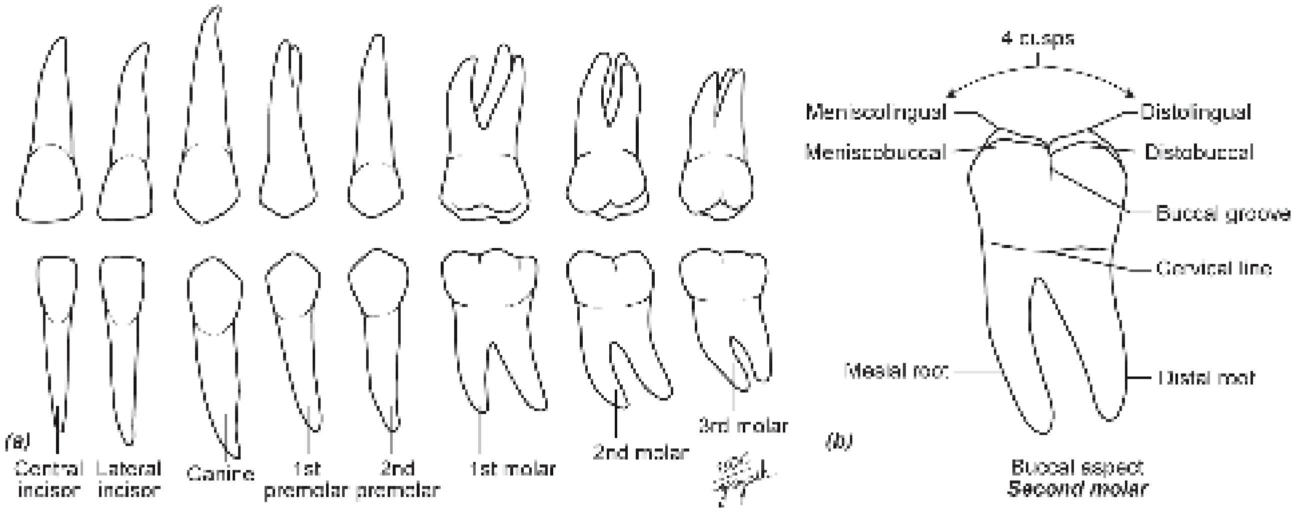

Ophthalmic nerve (V1)
Maxillary nerve (V2)
Trigeminal nerve
Mandibular nerve (V3)
Inferior alveolar nerve
Infraorbital nerve
Posterior
Middle
Anterior
Superior alveolar nerves
Dental branches
Superior dental plexus
Dental branches
Mylohyoid nerve
Incisive branch
Mental nerve

Fig. 14.4: Nerve supply of teeth


(a)
Central incisor
Lateral incisor
Canine
1st premolar
2nd premolar
1st molar
2nd molar
3rd molar
(b)
4 cusps
Meniscolingual
Meniscobuccal
Distolingual
Distobuccal
Buccal groove
Cervical line
Mesial root
Distal root
Buccal aspect
Second molar

Figs 14.5a and b: (a) Types of the permanent teeth (upper and lower teeth of the right side) and (b) buccal aspect of second molar tooth

portion of the maxilla. The lower edge of incisors partially covers the labial surface of mandibular incisor. Incisors have a single root and a sharp incisal edge. The incisors are useful for biting, cutting off pieces of food.

Canines

These are pointed teeth. There are total four canines, one in each quadrant and they are named as maxillary canines and mandibular canines. They lie behind and adjacent to the lateral incisors. They have single, pointed cusp and a single root. They have the longest root. They are prominent in carnivorous animal, hence called *canines*. They are the last deciduous teeth to erupt. They are used to tear the food.

Premolars *(Bicuspids)*

They are located behind the canine and in front of molars. There are eight premolars, two in each quadrant. They are named as first premolar (close to midline) and second premolar (farthest from the midline). Each premolar has at least two cusps (hence called *bicuspids*). The first premolar has two roots, and second premolar has single root. There are no premolars in the primary dentition. They are designated to crush the food.

Molars

They are located behind the canine in deciduous dentition and behind the premolars in permanent dentition. There are twelve molars (grinders in Latin), three on each quadrant. They are named as first, second, and third molars. The molars have 4–5 cups (four cups in upper molars and five cups in lower molars). Mandibular molars have two roots, whereas maxillary molars have three roots. Third molar tooth is known as *wisdom tooth*. It is mostly seen as impacted. They are designated for grinding the food.

STAGES OF DEVELOPMENT OF DECIDUOUS TEETH

1. *Stages of dental lamina*: During the 6th week of development, epithelium (ectoderm) in the region of developing alveolar process (U-shaped zone) thickens to form dental lamina (Fig. 14.6).

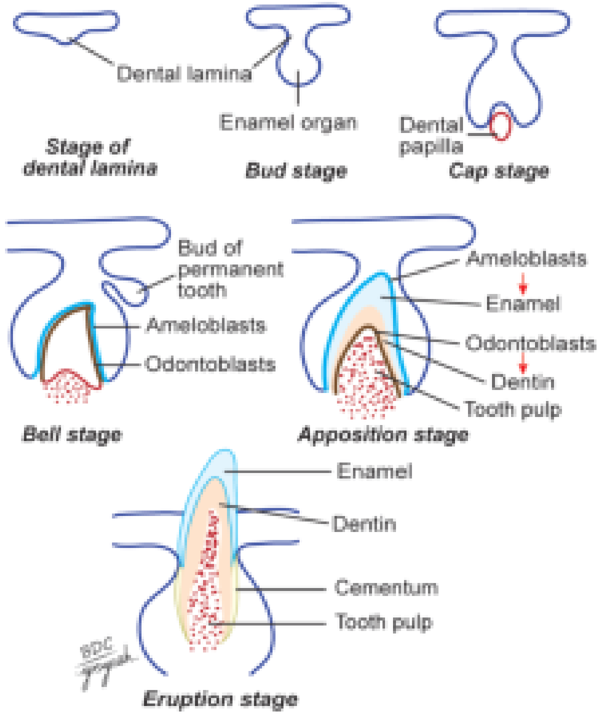

Dental lamina
Enamel organ
Dental papilla
Stage of dental lamina
Bud stage
Cap stage
Bud of permanent tooth
Ameloblasts
Odontoblasts
Bell stage
Ameloblasts
Enamel
Odontoblasts
Dentin
Tooth pulp
Apposition stage
Enamel
Dentin
Cementum
Tooth pulp
Eruption stage

Fig. 14.6: Development of tooth

2. *Bud stage*: In each alveolar process, the dental lamina thickens at ten places and forms tooth buds (enamel organ) that grow towards underlying mesoderm.
3. *Cap stage*: Mass of mesenchyme (mostly neural crest cells) occupies the core of enamel organ and makes enamel organ cap-shaped. In the 8th week, enamel organs appear. This mass of the mesenchyme forms the dental papilla. In 10th week, enamel organs become cap-shaped.
4. *Bell stage*: Cells of the enamel organ facing dental papilla become columnar and form ameloblasts.

   Cells of the dental papilla facing ameloblasts, later form an epithelium-like layer called odontoblasts. Enamel organ soon forms:

   - outer cell layer as outer dental epithelium,
   - inner cell layer as inner dental epithelium (ameloblasts), and
   - central core loose mesenchymal cells as stellate reticulum or enamel reticulum.

   Growing dental cap forms a bell-shaped structure over underlying dental papilla; hence, called bell stage.
5. *Apposition stage*: Ameloblasts lay down enamel on the outer surface of basement membrane separating ameloblasts and odontoblasts, whereas odontoblast lays down dentin on deeper surface of basement membrane. The ameloblasts move towards outer dental epithelium through satellite reticulum. Finally, outer epithelium, reticulum and ameloblasts disappear, leaving behind dental cuticle of Nasmyth (a thin layer) over enamel. On the formation of dentin, regressing odontoblast leaves behind their cytoplasmic processes (called odontoblastic processes or Tomes processes) that remain trapped in dentin.

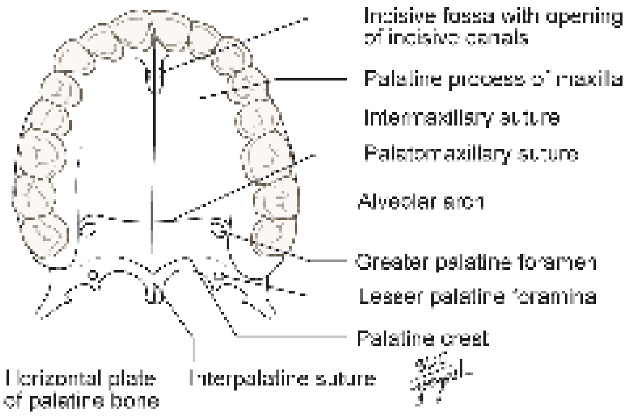

Incisive fossa with opening of incisive canals
Palatine process of maxilla
Intermaxillary suture
Palatomaxillary suture
Alveolar arch
Greater palatine foramen
Lesser palatine foramina
Palatine crest
Horizontal plate of palatine bone
Interpalatine suture

Fig. 14.7: Hard palate

   Continuous deposition of dentin reduces pulp cavity to a narrow pulp canal. Blood vessels and nerves reach tooth through the pulp canal. Mesenchymal cells covering the root of the tooth modify to form cementoblasts. The cementoblasts lay down a layer of dense bone called cementum. Cementum is produced just before the birth. Mesenchymal cells covering cementum form periodontal ligament that connects root of the tooth with jaw bone. After birth, before eruption of tooth, periodontal ligament appears.
6. *Eruption stage*: Growth of the root produces eruption of tooth. Eruption age of various teeth is listed in Table 14.2.

Formation of permanent teeth: These develop from the dental buds arising from the dental lamina and lie on the medial side of each developing milk tooth.

HARD PALATE

It is a partition between the nasal and oral cavities. Its anterior 2/3rd are formed by the palatine processes of the maxillae; and its posterior 1/3rd by the horizontal plates of the palatine bones (Plate 14.1 and Fig. 14.7).

Features

1. *Anterolateral margins* of the palate are continuous with the alveolar arches and gums.
2. *Posterior margin* gives attachment to the soft palate.
3. *Superior surface* forms the floor of the nose.
4. *Inferior surface* forms the roof of the oral cavity.

Vessels and Nerves

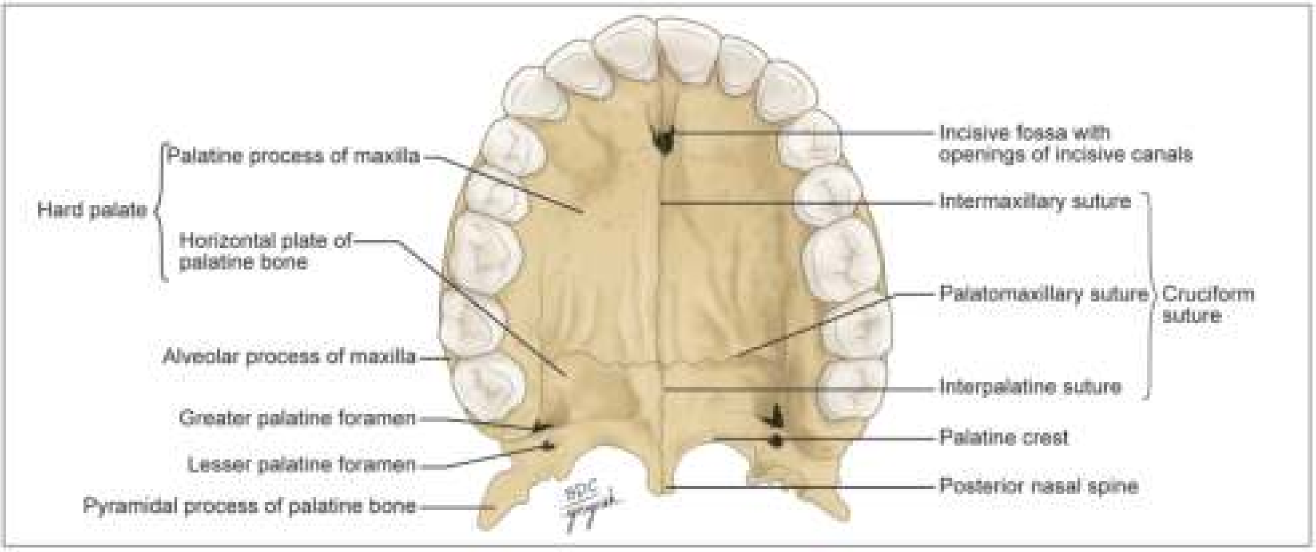
Arteries: Greater palatine branch of maxillary artery.

Veins: Drain into the pterygoid plexus of veins.

Nerves: Greater palatine and nasopalatine branches of the pterygopalatine ganglion suspended by the maxillary nerve.

Lymphatics: The lymphatics drain mostly to the upper deep cervical nodes and partly to the retropharyngeal nodes.

Plate 14.1: Hard palate (inferior view)


Hard palate
Palatine process of maxilla
Horizontal plate of palatine bone
Alveolar process of maxilla
Greater palatine foramen
Lesser palatine foramen
Pyramidal process of palatine bone
Incisive fossa with openings of incisive canals
Intermaxillary suture
Palatomaxillary suture
Cruciform suture
Interpalatine suture
Palatine crest
Posterior nasal spine

DISSECTION

Cut through the centre of the frontal bone, internasal suture, intermaxillary sutures, chin, hyoid bone, thyroid, cricoid and tracheal cartilages; carry the incision through the septum of nose, nasopharynx, tongue, and both the palates.

Cut through the centre of the remaining occipital bone and cervical vertebrae. This will complete the *sagittal section of head and neck*.

Hard palate: Strip the mucoperiosteum of hard palate.

Soft palate: Remove the mucous membrane of the soft palate in order to identify its muscles. Also remove the mucous membrane over palatoglossal and palatopharyngeal arches and salpingopharyngeal fold to visualise the subjacent muscles.

Competency:

AN36.2 Describe the: (1) morphology, relations, blood supply and applied anatomy of palatine tonsil, (2) composition of soft palate.

SOFT PALATE

It is a movable, muscular fold, suspended from the posterior border of the hard palate.

It separates the nasopharynx from the oropharynx, the crossroads between the food and air passages (Fig. 14.8 and Flowchart 14.1).

External Features

The soft palate has two surfaces—anterior and posterior:

1. ***Anterior (oral) surface*** is concave and is marked by a median raphe.
2. ***Posterior surface*** is convex, and is continuous superiorly with the floor of the nasal cavity.

The soft palate has two borders—superior and inferior:

1. ***Superior border*** is attached to the posterior border of the hard palate, blending on each side with the pharynx.

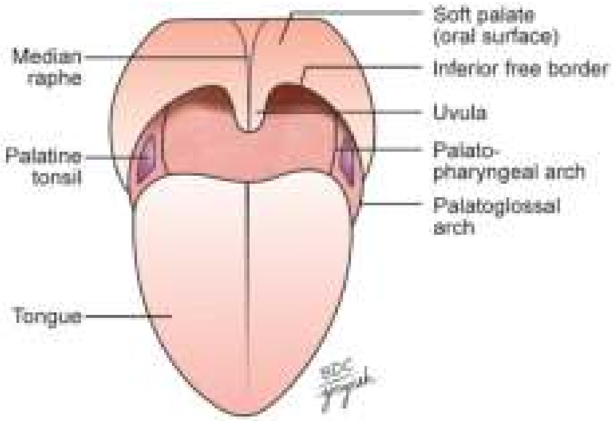

Median raphe
Palatine tonsil
Tongue
Soft palate (oral surface)
Inferior free border
Uvula
Palato-pharyngeal arch
Palatoglossal arch

Fig. 14.8: Soft palate with palatine tonsils

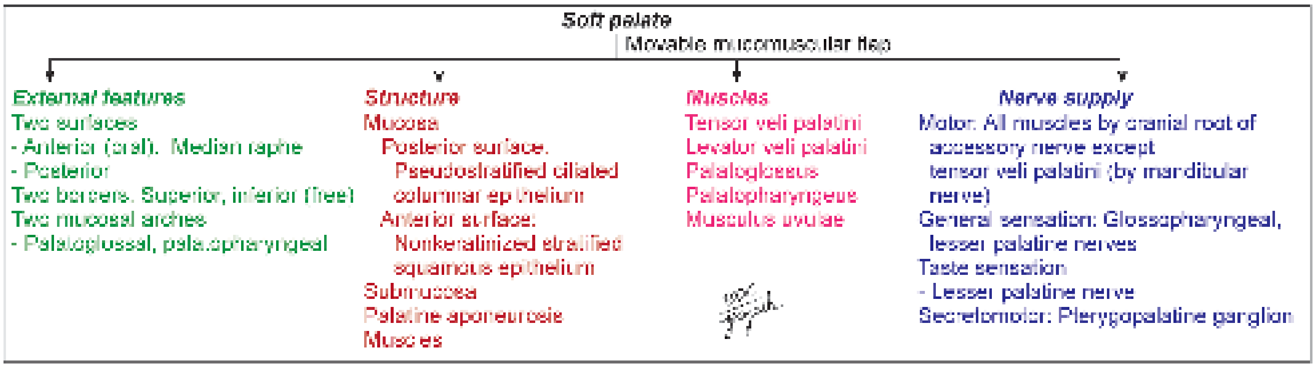
2. ***Inferior border*** is free and bounds the pharyngeal isthmus. From its middle, there hangs a conical projection, called the ***uvula***. From each side of the base of the uvula (Latin *small grape*), two curved folds of mucous membrane extend laterally and downwards as follows:
   a. The anterior fold is called the ***palatoglossal arch*** or anterior pillar of fauces. It contains the palatoglossus muscle and reaches the side of the tongue at the junction of its oral and pharyngeal parts. This fold forms the lateral boundary of the oropharyngeal isthmus or isthmus of fauces.
   b. The posterior fold is called the ***palatopharyngeal arch*** or posterior pillar of fauces. It contains the palatopharyngeus muscle. It forms the posterior boundary of the tonsillar fossa, and merges inferiorly with the lateral wall of the pharynx.

Structure

The soft palate is a fold of mucous membrane containing the following parts:

- The palatine aponeurosis which is the flattened tendon of the tensor veli palatini forms the fibrous basis of the

Flowchart 14.1: Soft palate


Soft palate
Movable mucomuscular flap
External features
Two surfaces
- Anterior (oral). Median raphe
- Posterior
Two borders. Superior, inferior (free)
Two mucosal arches
- Palatoglossal, palatopharyngeal
Structure
Mucosa
Posterior surface.
Pseudostratified ciliated columnar epithelium
Anterior surface:
Nonkeratinized stratified squamous epithelium
Submucosa
Palatine aponeurosis
Muscles
Muscles
Tensor veli palatini
Levator veli palatini
Palatoglossus
Palatopharyngeus
Musculus uvulae
Nerve supply
Motor: All muscles by cranial root of accessory nerve except tensor veli palatini (by mandibular nerve)
General sensation: Glossopharyngeal, lesser palatine nerves
Taste sensation
- Lesser palatine nerve
Secretomotor: Pterygopalatine ganglion

palate. Near the median plane, the aponeurosis splits to enclose the musculus uvulae.

- The levator veli palatini and the palatopharyngeus lie on the superior surface of the palatine aponeurosis.
- The palatoglossus lies on the inferior or anterior surface of the palatine aponeurosis.
- Numerous mucous glands, and some taste buds are present.

Soft palate comprises epithelium, connective tissue and muscles. Epithelium is from the ectoderm of maxillary process. The muscles are derived from 1st, 4th and 6th branchial arches and accordingly are innervated by mandibular and vagoaccessory complex.

Muscles of the Soft Palate

They are as follows (Plate 14.2 and Fig. 14.9):

1. Tensor palati (tensor veli palatini)
2. Levator palati (levator veli palatini)
3. Musculus uvulae
4. Palatoglossus
5. Palatopharyngeus.

The origin, insertion and actions of these muscles are given in Table 14.3.

Blood Supply

Arteries

1. Greater palatine branch of maxillary artery.
2. Ascending palatine branch of facial artery.
3. Palatine branch of ascending pharyngeal artery.

Veins

They pass to the pterygoid and tonsillar plexuses of veins.

Lymphatics

Drain into the upper deep cervical and retropharyngeal lymph nodes.

Nerve Supply

1. *Motor nerves*. All muscles of the soft palate except the tensor veli palatini are supplied by the pharyngeal plexus. The fibres of this plexus are derived from the cranial part of the accessory nerve through the vagus. The tensor veli palatini is supplied by the mandibular nerve.
2. **General** ***sensory nerves*** are derived from:
   a. The middle and posterior lesser palatine nerves, which are branches of the maxillary nerve through the pterygopalatine ganglion.
   b. The glossopharyngeal nerve.
3. ***Special sensory*** or *gustatory nerves*, carrying *taste sensations* from the oral surface, are contained in the lesser palatine nerves. The fibres travel through the greater petrosal nerve to the geniculate ganglion of the facial nerve and from there to the nucleus of the tractus solitarius.
4. ***Secretomotor nerves*** are also contained in the lesser palatine nerves. They are derived from the superior salivatory nucleus and travel through the greater petrosal nerve.

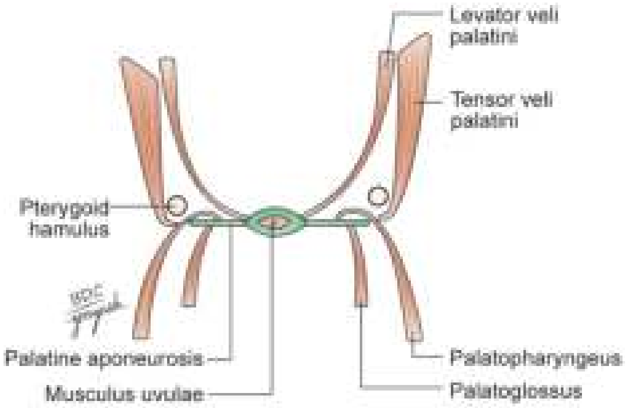

Levator veli palatini
Tensor veli palatini
Pterygoid hamulus
Palatine aponeurosis
Musculus uvulae
Palatopharyngeus
Palatoglossus

Fig. 14.9: Muscles of soft palate

Passavant's Ridge

Some of the upper fibres of the palatopharyngeus pass circularly deep to the mucous membrane of the pharynx, to form a sphincter internal to the superior constrictor. These fibres constitute Passavant's muscle which on contraction raises a ridge called the Passavant's ridge on the posterior wall of the nasopharynx. When the soft palate is elevated it comes in contact with this ridge, the two together closing the pharyngeal isthmus between the nasopharynx and the oropharynx (Fig. 14.10).

Plate 14.2: Muscles of the soft palate

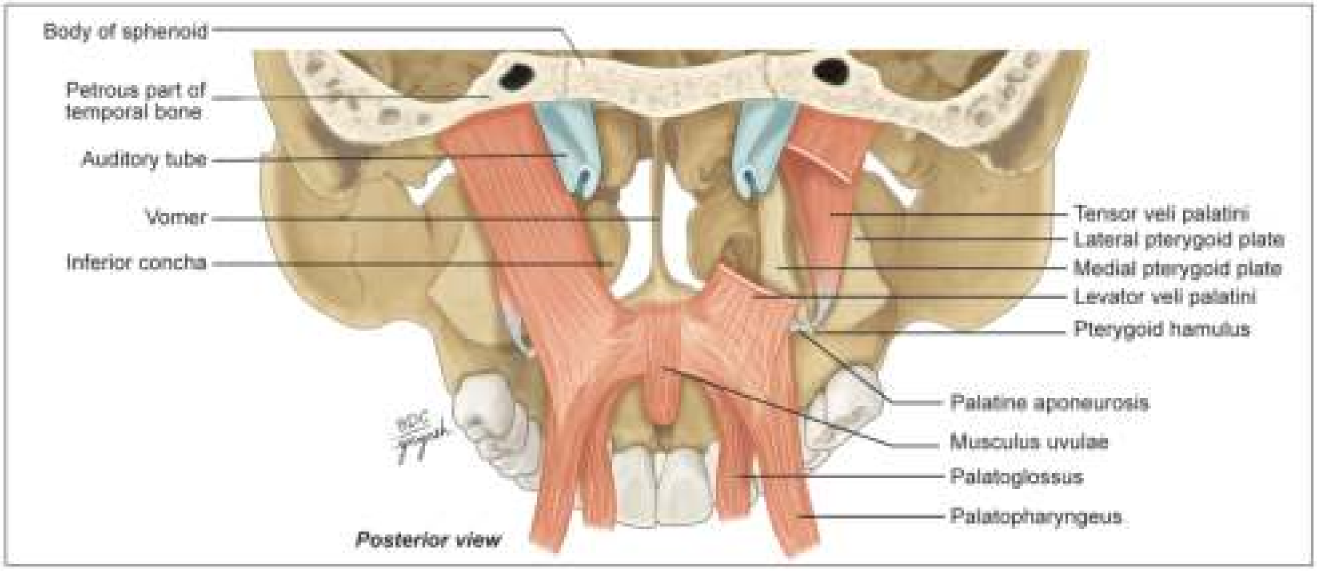

Body of sphenoid
Petrous part of temporal bone
Auditory tube
Vomer
Inferior concha
Tensor veli palatini
Lateral pterygoid plate
Medial pterygoid plate
Levator veli palatini
Pterygoid hamulus
Palatine aponeurosis
Musculus uvulae
Palatoglossus
Palatopharyngeus
Posterior view

TABLE 14.3: Origin, insertion and actions of muscles of the soft palate (Plate 14.2 and Fig. 14.9)

Muscle	*Origin*	*Insertion*	*Actions*
1. **Tensor veli palatini** This is a thin, triangular muscle	a. Lateral side of auditory tube b. Adjoining part of the base of the skull (greater wing and scaphoid fossa of sphenoid bone)	Muscle descends, converges to form a delicate tendon which winds round the pterygoid hamulus, passes through the origin of the buccinator, and flattens out to form the palatine aponeurosis. Aponeurosis is attached to: a. Posterior border of hard palate b. Inferior surface of palate behind the palatine crest	a. Tightens the soft palate, chiefly the anterior part b. Opens the auditory tube to equalize air pressure between the middle ear and the nasopharynx
2. **Levator veli palatini** This is a cylindrical muscle that lies deep to the tensor veli palatini	a. Inferior aspect of auditory tube b. Adjoining part of inferior surface of petrous temporal bone	Muscle enters the pharynx by tube passing over the upper concave margin of the superior constrictor, runs downwards and medially and spreads out in the soft palate. It is inserted into the upper surface of the palatine aponeurosis	a. Elevates soft palate and closes the pharyngeal isthmus b. Opens the auditory tube like the tensor veli palatini
3. **Musculus uvulae** This is a longitudinal strip placed on each side of the median plane, within the palatine aponeurosis	a. Posterior nasal spine b. Palatine aponeurosis	Mucous membrane of uvula	Pulls up the uvula
4. **Palatoglossus**	Oral surface of palatine aponeurosis	Descends in the palatoglossal arch, to the side of the tongue at the junction of its oral and pharyngeal parts	Pulls up the root of the tongue, approximates the palatoglossal arches, and thus closes the oropharyngeal isthmus
5. **Palatopharyngeus** It consists of two fasciculi that are separated by the levator veli palatini (also *see* Passavant's ridge)	a. Anterior fasciculus from posterior border of hard palate b. Posterior fasciculus from the palatine aponeurosis	Descends in the palatopharyngeal arch and spreads out to form the greater part of longitudinal muscle coat of pharynx. It is inserted into: a. Posterior border of the lamina of the thyroid cartilage b. Wall of the pharynx and its median raphe	Pulls up the wall of the pharynx and shortens it during swallowing

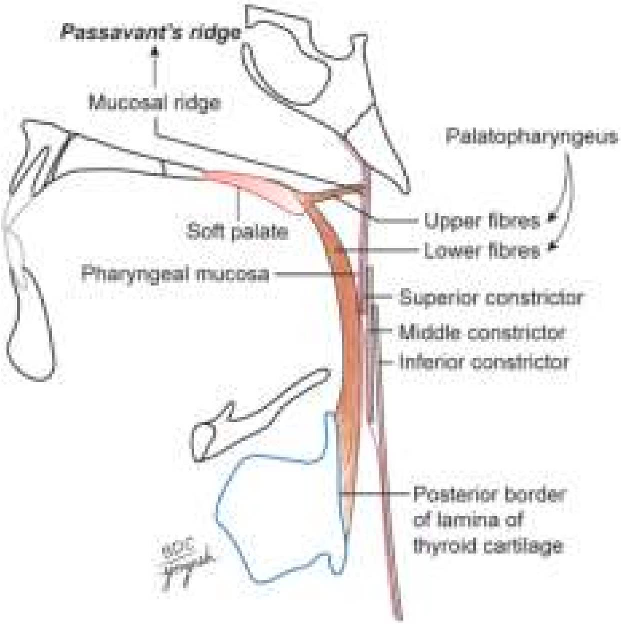

Passavant's ridge
Mucosal ridge
Palatopharyngeus
Upper fibres
Lower fibres
Soft palate
Pharyngeal mucosa
Superior constrictor
Middle constrictor
Inferior constrictor
Posterior border of lamina of thyroid cartilage

Fig. 14.10: Passavant's ridge

Movements and Functions of the Soft Palate

1. Soft palate separates the oropharynx from nasopharynx during swallowing to prevent the entry of food into nose.
2. Separates oral cavity from oropharynx to facilitate chewing and breathing simultaneously.
3. Voice modulation.
4. Protection of nasal mucosa by diverting airflow through the mouth during sneezing.
5. Prevent entry of mucous into nose during coughing.

CLINICAL ANATOMY

- ***Paralysis of the soft palate*** in lesions of the vagus nerve produces:
  1. Nasal regurgitation of liquids
  2. Nasal twang in voice
  3. Flattening of the palatal arch
  4. Deviation of uvula to normal side (Fig. 14.11).
- Choking by food/fluid causes laryngeal obstruction and asphyxia. Heimlich manoeuver can remove the obstruction.

Heimlich Manoeuvre

Stand behind the patient. Pass your arm under his arm. Put hand in his epigastrium; one hand made into a fist and other hand over fist. Give 3–4 abdominal thrusts directed upwards and backwards. This helps in squeezing residual air from lungs in trachea, and larynx, dislodges the foreign body and relieves laryngeal obstruction.

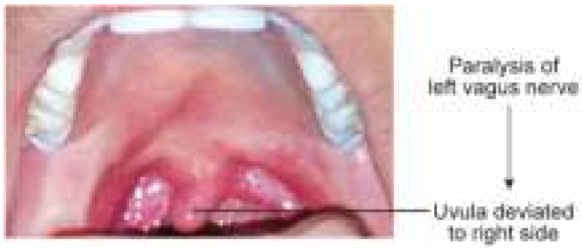

Paralysis of left vagus nerve
Uvula deviated to right side

Fig. 14.11: Uvula deviated to right side in paralysis of left vagus nerve

Competency:

AN43.4 Describe the development and developmental basis of congenital anomalies of face, palate, tongue, branchial apparatus, pituitary gland, thyroid gland and eye (Palate is described here. For the rest of organs, please see respective chapters.)

DEVELOPMENT OF PALATE

Palatogenesis takes place between 5th week and 12th week of IUL (Fig. 14.12 and Flowchart 14.2).

Primary palate: In sixth week, the intermaxillary segment forms a shelf-like projection (that later bears upper four incisor teeth), called primary palate or median palatine process. Later, primary palate forms premaxillary part of the maxilla.

Secondary palate: In sixth week, two mesenchymal projections extend from the inner aspects of maxillary processes. These projections are called secondary palate or lateral palatine processes. During 7th–8th weeks, the lateral palatine processes elongate and fuse:

1. With each other in the midline
2. With nasal septum
3. With posterior part of the primary palate.

Formation of definitive palate: The primary palate fuses with secondary palate to form definitive palate. Incisive foramen divides primary and secondary palates.

- Anterior three-fourths of the definitive palate ossifies and forms hard palate.
- Posterior one-fourth of the definitive palate remains unossified and forms soft palate with uvula.

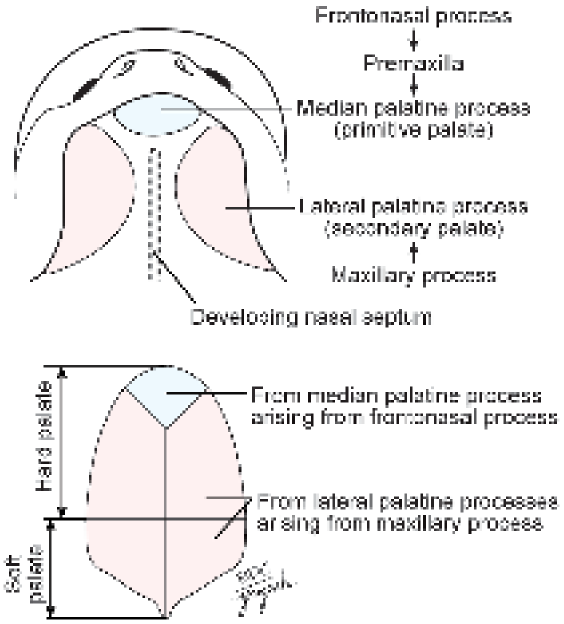
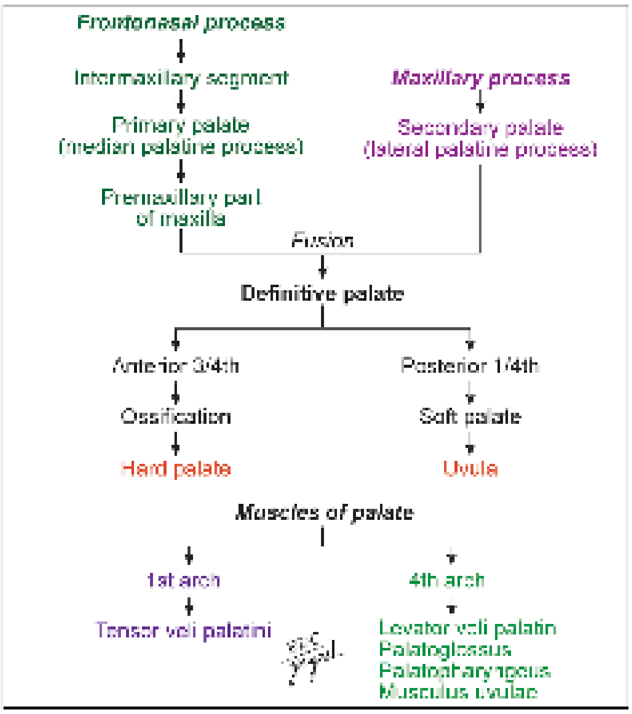

Frontonasal process
Premaxilla
Median palatine process (primitive palate)
Lateral palatine process (secondary palate)
Maxillary process
Developing nasal septum
Hard palate
Soft palate
From median palatine process arising from frontonasal process
From lateral palatine processes arising from maxillary process

Fig. 14.12: Development of the palate

Flowchart 14.2: Development of the palate


Frontonasal process
Intermaxillary segment
Maxillary process
Primary palate (median palatine process)
Secondary palate (lateral palatine process)
Premaxillary part of maxilla
Fusion
Definitive palate
Anterior 3/4th
Posterior 1/4th
Ossification
Soft palate
Hard palate
Uvula
Muscles of palate
1st arch
4th arch
Tensor veli palatini
Levator veli palatini
Palatoglossus
Palatopharyngeus
Musculus uvulae

- Small persistent nasopalatine canal in the median plane of premaxilla forms the incisive fossa. In the incisive fossa, right and left incisive canals open.

Muscles of palate: Mesoderm of branchial arches invades soft palate to form muscles as follows:

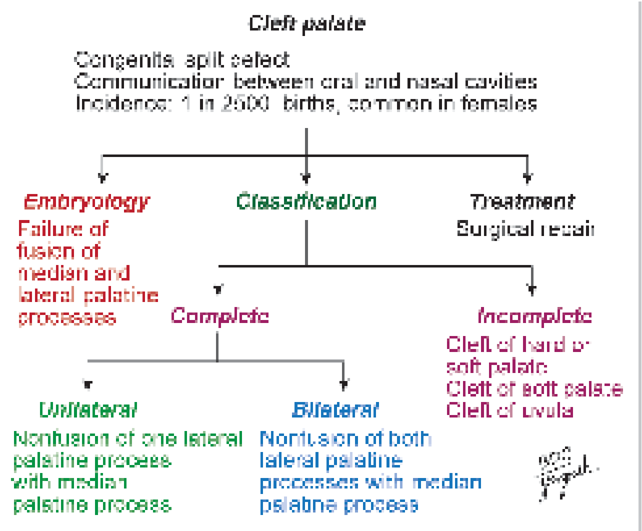
- Tensor veli palatini – from 1st arch
- Levator veli palatini, palatoglossus, palatopharyngeus, musculus uvulae – from 4th arch.

CLINICAL ANATOMY

Cleft palate

- Cleft palate is a congenital split defect of palate that causes communication between oral and nasal cavities (Figs 14.13 and 14.14, Flowchart 14.3). Patient with cleft palate usually has eating, speech, and dental problems. The commonest cause is multifactorial inheritance.
- *Incidence*
  - 1 in 2500 births.
  - Cleft palate is more common in females (67%).
  - Incidence of cleft palate is not related to the maternal age.
  - If a couple has a child with cleft palate, there are 2% chances that another baby will have cleft palate.
  - Unilateral cleft of upper lip is the commonest congenital anomaly of face.
- *Embryological basis*
  - Nonfusion of median and lateral palatine processes, and the nasal septum results in cleft palate.
- Classification: Cleft palate may be complete or incomplete (partial) (Flowchart 14.3).
  1. Complete cleft palate may be unilateral or bilateral.
     - *Unilateral complete cleft palate*: It results due to nonfusion of one lateral palatine process of the maxilla with the median palatine process of premaxilla and also the nonfusion of the two lateral palatine processes. It is always associated with harelip on the same side of the defect.
     - *Bilateral complete cleft palate*: It results due to nonfusion of both the lateral palatine process of maxilla and the median palatine process of premaxilla.
  2. Incomplete cleft palate may be cleft of hard and soft palate or only the cleft of soft palate or uvula.

Flowchart 14.3: Cleft palate


Cleft palate
Congenital split defect
Communication between oral and nasal cavities
Incidence: 1 in 2500 births, common in females
Embryology
Failure of fusion of median and lateral palatine processes
Classification
Treatment
Surgical repair
Complete
Incomplete
Cleft of hard or soft palate
Cleft of soft palate
Cleft of uvula
Unilateral
Nonfusion of one lateral palatine process with median palatine process
Bilateral
Nonfusion of both lateral palatine processes with median palatine process

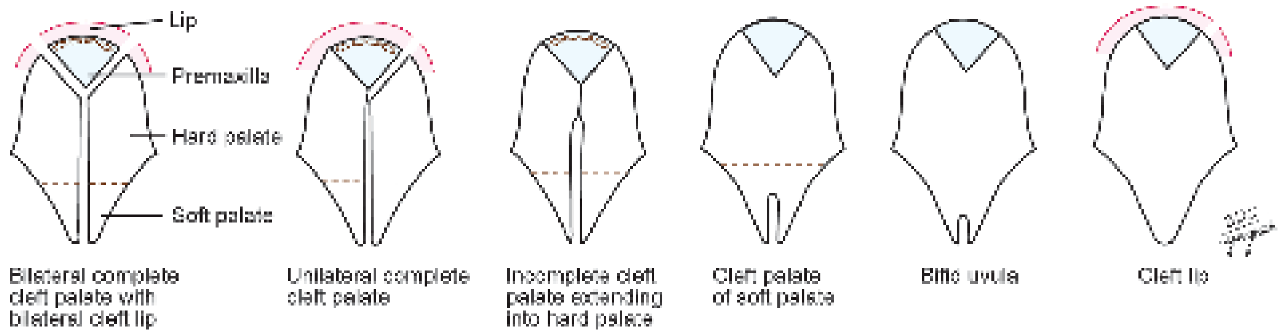
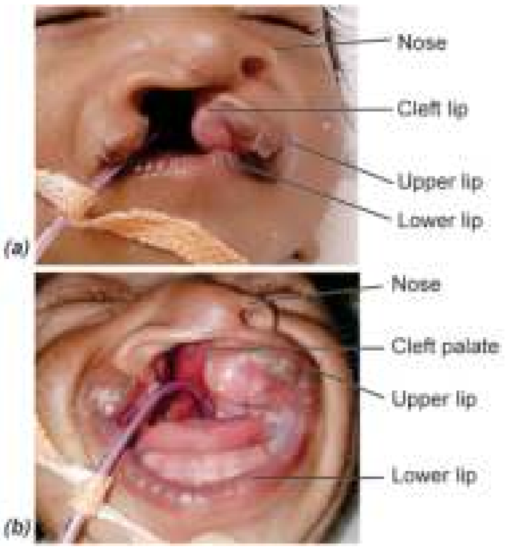

Lip
Premaxilla
Hard palate
Soft palate
Bilateral complete cleft palate with bilateral cleft lip
Unilateral complete cleft palate
Incomplete cleft palate extending into hard palate
Cleft palate of soft palate
Bifid uvula
Cleft lip

Fig. 14.13: Types of congenital cleft palate


Nose
Cleft lip
Upper lip
Lower lip
(a)
Nose
Cleft palate
Upper lip
Lower lip
(b)

Figs 14.14a and b: A 5-day-old baby with unilateral cleft lip and cleft palate (on the right side)

Competency:
AN36.3 Describe and demonstrate the muscles, nerve supply, blood supply and lymphatic drainage of the pharynx.

PHARYNX

The pharynx (Latin *throat*) is a wide muscular tube, situated behind the nose, the mouth and the larynx. Clinically, it is a part of the upper respiratory passages where infections are common. The upper part of the pharynx transmits only air, the lower part (below the inlet of the larynx), only food, but the middle part is a common passage for both air and food. The nasopharynx part of pharynx is connected to the middle ear via the pharyngotympanic tube (Figs 14.15 to 14.18).

Dimensions of Pharynx

Length: About 12–14 cm.

Width:

1. Upper part is the widest (3.5 cm) and non-collapsible
2. Middle part is narrow.
3. The lower end is the narrowest part of the gastrointestinal tract (except for the vermiform).

Boundaries (Figs 14.15 to 14.18)

Superiorly: Base of the skull, including the posterior part of the body of the sphenoid and the basilar part of the occipital bone, in front of the pharyngeal tubercle.

Inferiorly: The pharynx is continuous with the oesophagus at the level of the sixth cervical vertebra, corresponding to the lower border of the cricoid cartilage.

Posteriorly: The pharynx glides freely on the prevertebral fascia which separates it from the cervical vertebral bodies.

Anteriorly: It communicates with the nasal cavity, the oral cavity and the larynx. Thus, the anterior wall of the pharynx is incomplete.

On each side

- Auditory tube
- Styloid process and the muscles attached to it
- The common carotid, internal carotid, and external carotid arteries
- The last four cranial nerves.

Parts of the Pharynx

The cavity of the pharynx is divided into (Fig. 14.18):

1. Nasal part—*nasopharynx*
2. Oral part—*oropharynx*
3. Laryngeal part—*laryngopharynx*.

Comparison between nasopharynx, oropharynx and laryngopharynx shown in Table 14.4.

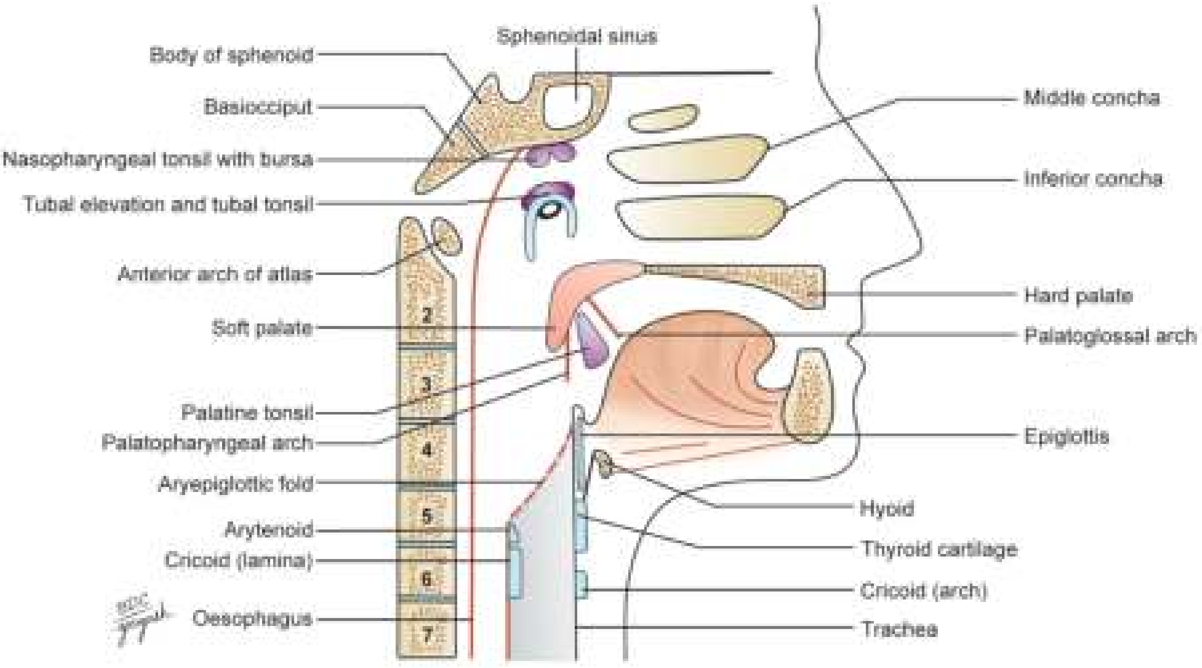

Sphenoidal sinus
Body of sphenoid
Basiocciput
Nasopharyngeal tonsil with bursa
Tubal elevation and tubal tonsil
Anterior arch of atlas
Soft palate
Palatine tonsil
Palatopharyngeal arch
Aryepiglottic fold
Arytenoid
Cricoid (lamina)
Oesophagus
Middle concha
Inferior concha
Hard palate
Palatoglossal arch
Epiglottis
Hyoid
Thyroid cartilage
Cricoid (arch)
Trachea
2
3
4
5
6
7

Fig. 14.15: Sagittal section through the pharynx, nose, mouth and larynx

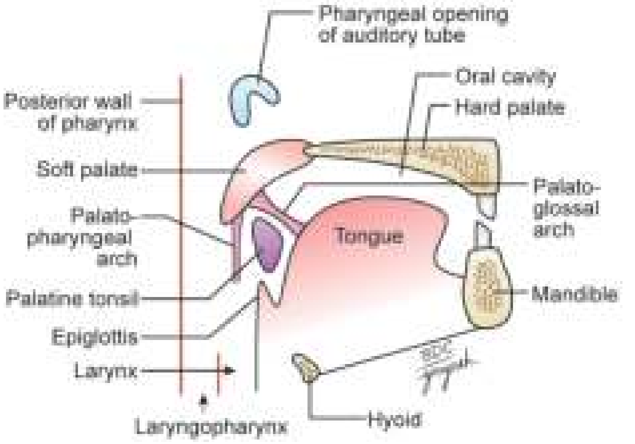

Pharyngeal opening of auditory tube
Oral cavity
Hard palate
Posterior wall of pharynx
Soft palate
Palato-pharyngeal arch
Tongue
Palato-glossal arch
Palatine tonsil
Mandible
Epiglottis
Larynx
Laryngopharynx
Hyoid

Fig. 14.16: Sagittal section through the mouth and pharynx

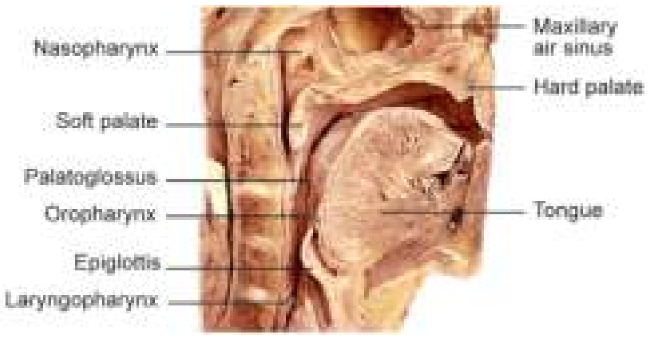

Nasopharynx
Maxillary air sinus
Hard palate
Soft palate
Palatoglossus
Tongue
Oropharynx
Epiglottis
Laryngopharynx

Fig. 14.17: Sagittal section of pharynx

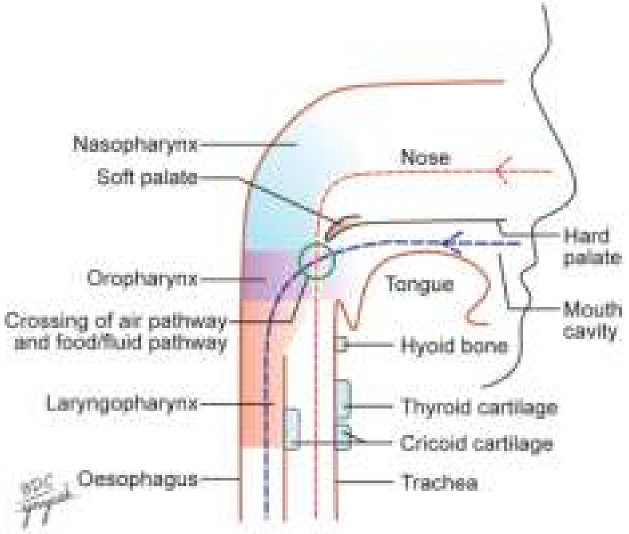

Nasopharynx
Soft palate
Nose
Hard palate
Oropharynx
Tongue
Mouth cavity
Crossing of air pathway and food/fluid pathway
Hyoid bone
Laryngopharynx
Thyroid cartilage
Cricoid cartilage
Oesophagus
Trachea

Fig. 14.18: Crossing of upper airway and upper food passages

DISSECTION

Identify the structures in the interior of three parts of pharynx, i.e. nasopharynx, oropharynx and laryngopharynx. Clean the surfaces of buccinator muscle and adjoining superior constrictor muscles by removing connective tissue and buccopharyngeal fascia over these muscles. Detach the medial pterygoid muscle from its origin and reflect it downwards. This will expose the superior constrictor muscle completely.

TABLE 14.4: Comparison between nasopharynx, oropharynx and laryngopharynx

Particulars	*Nasopharynx*	*Oropharynx*	*Laryngopharynx*
Situation	Behind nose	Behind oral cavity	Behind larynx
Extent	Base of skull (body of sphenoid) to soft palate	Soft palate to upper border of epiglottis (Figs 14.9a and b)	Upper border of epiglottis to lower border of cricoid cartilage
Communications	Anteriorly with nose (Fig. 14.9a) Below with oropharynx	1. Anteriorly with oral cavity 2. Above with nasopharynx 3. Below with laryngopharynx	Inferiorly with oesophagus Anteriorly with larynx (Fig.14.9b) Above with oropharynx
Nerve supply	Pharyngeal branches of pterygopalatine ganglion	IX and X nerves	IX and X nerves
Relations:			
i. Anterior	Posterior nasal aperture	Oral cavity	1. Inlet of larynx 2. Posterior surface of cricoid cartilage 3. Arytenoid cartilage
ii. Posterior and roof	Body of sphenoid bone and basiocciput and anterior arch of atlas Presence of: a. Nasopharyngeal tonsil prominent in children b. Nasopharyngeal bursa—mucus diverticulum	Body of second and third cervical vertebrae	Fourth and fifth cervical vertebrae
iii. Lateral wall	Opening of auditory tube above tube is tubal elevation with tubal tonsil	Tonsillar fossa containing palatine tonsils	Piriform fossa on each side of inlet of larynx, bounded by aryepiglottic fold medially and thyroid cartilage laterally.
Lining epithelium	Ciliated columnar epithelium	Stratified squamous nonkeratinised epithelium	Stratified squamous nonkeratinised epithelium
Function	Passage for air (respiratory function)	Passage for air and food	Passage for food

Laryngeal Part of Pharynx (Laryngopharynx)

This is the lower part of the pharynx situated behind the larynx. It extends from the upper border of the epiglottis to the lower border of the cricoid cartilage.

The *anterior wall* presents:

a. The inlet of the larynx (Plate 14.3)
b. The posterior surfaces of the cricoid and arytenoid cartilages.

The *posterior wall* is supported mainly by the fourth and fifth cervical vertebrae, and partly by the third and sixth vertebrae. In this region, the posterior wall of the pharynx is formed by the superior, middle and inferior constrictors of the pharynx (Fig. 14.19).

The *lateral wall* presents a depression called the ***piriform fossa***, one on each side of the inlet of the larynx (Fig. 14.20). The fossa is bounded medially by the aryepiglottic fold, and laterally by the thyroid cartilage and the thyrohyoid membrane. Beneath the mucosa of fossa, there lies the internal laryngeal nerve. Removal of foreign bodies from the piriform fossa may damage the internal laryngeal nerve, leading to anaesthesia in the supraglottic part of the larynx.

Structure of Pharynx

The wall of the pharynx is composed of the following five layers from within outwards (Fig. 14.21):

1. *Mucosa*
2. *Submucosa*
3. ***Pharyngobasilar fascia*** or pharyngeal aponeurosis. This is a fibrous sheet internal to the pharyngeal muscles. It is thickest in the upper part where it fills the gap between the upper border of the superior constrictor and the base of the skull, and also posteriorly where it forms pharyngeal raphe. Superiorly, the fascia is attached to basiocciput, the petrous temporal bone, the auditory tube, posterior border of the medial pterygoid plate, and pterygomandibular raphe. Inferiorly, it is gradually lost deep to muscles, and hardly extend beyond the superior constrictor.
4. The ***muscular coat*** consists of an outer circular layer made up of the three constrictors (*superior, middle* and *inferior*) and an inner longitudinal layer made up of the stylopharyngeus, the salpingopharyngeus and the palatopharyngeus muscles. These muscles are described later.
5. The ***buccopharyngeal fascia*** covers the outer surface of the constrictors of the pharynx and extends forwards across the pterygomandibular raphe to cover the buccinator. Like the pharyngobasilar fascia, the buccopharyngeal fascia is best developed in the upper part of the pharynx.

Between the buccopharyngeal fascia and the muscular coat, there are the pharyngeal plexuses of veins and nerves (Fig. 14.21).

Muscles of Pharynx

Constrictors of the Pharynx

The muscular basis of the wall of the pharynx is formed mainly by the three pairs of constrictors—superior, middle and inferior (Plate 14.4, Table 14.5 and Flowchart 14.4). The *inferior constrictor* consists of two parts: *thyropharyngeus* and *cricopharyngeus*.

Median raphe: All the constrictors of the pharynx are inserted into a median raphe on the posterior wall of the pharynx. The upper end of the raphe reaches the base of the skull where it is attached to the pharyngeal tubercle on the basilar part of the occipital bone (Fig. 14.22).

Note: The origins of the constrictors are situated anteriorly in relation to the posterior openings of the nose—the mouth and the larynx. From here their fibres pass into the lateral and posterior walls of the pharynx, the fibres of the two sides meeting in the midline in a fibrous raphe.

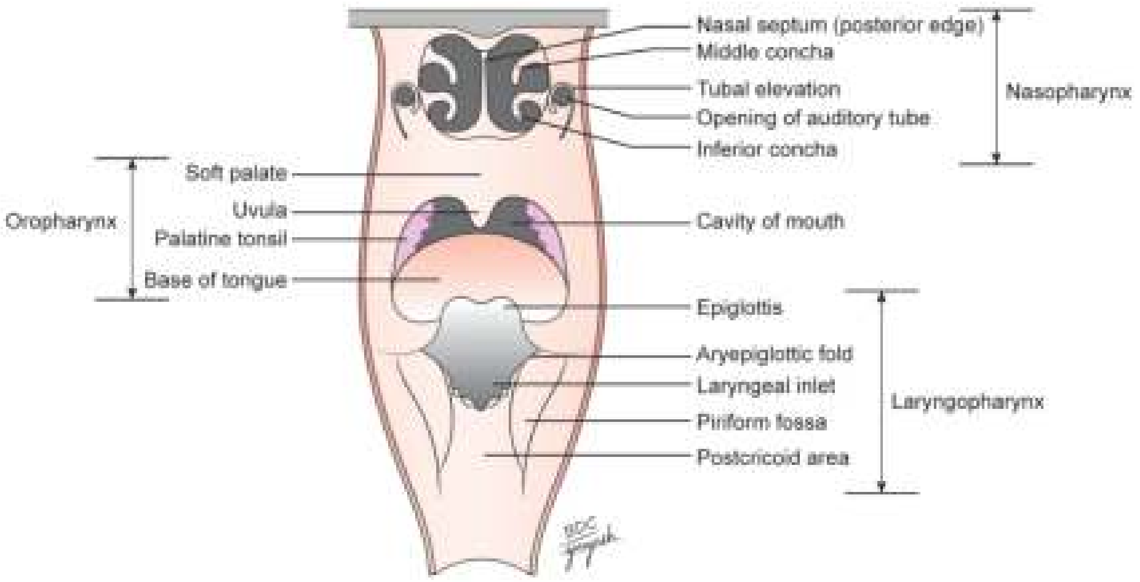
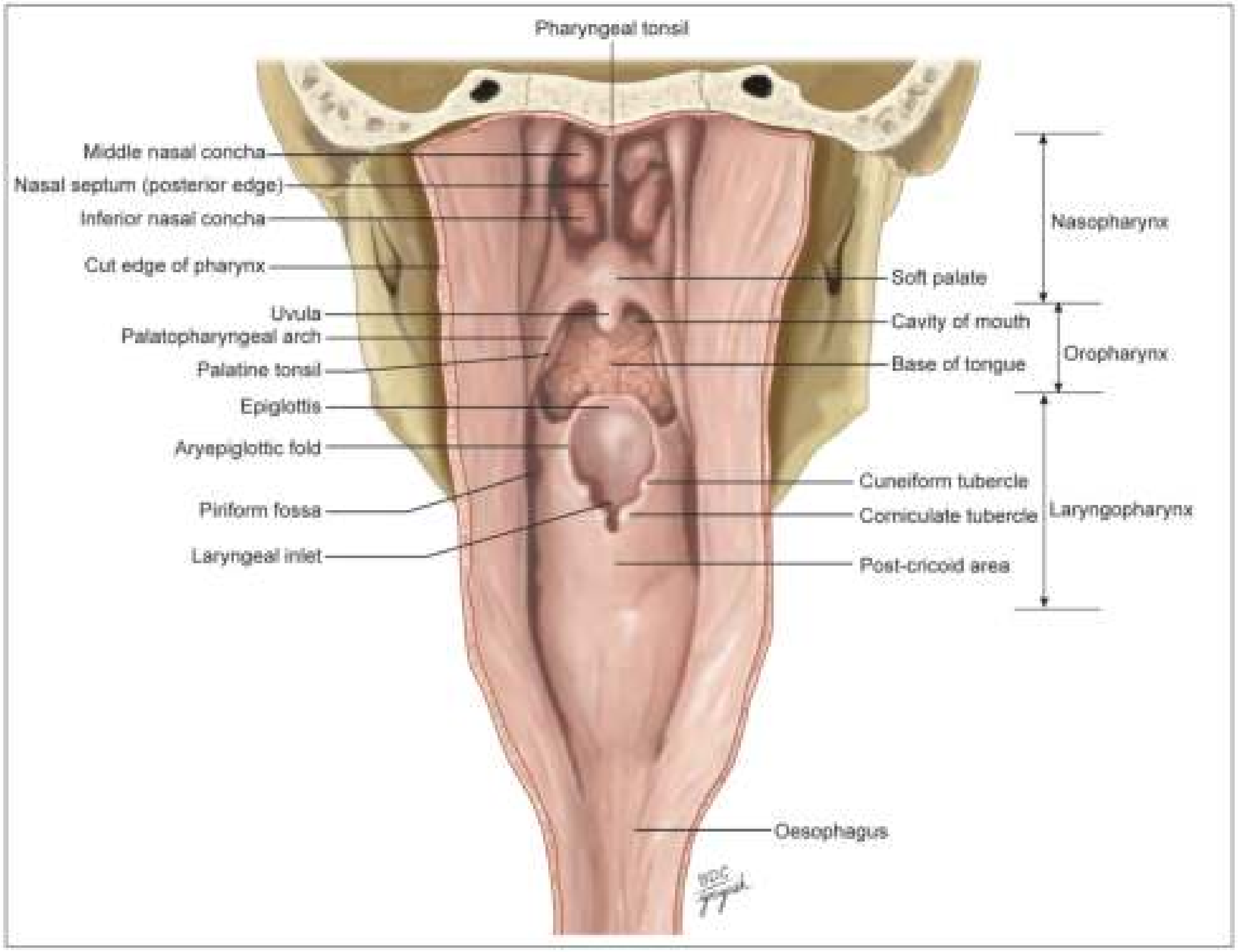


Fig. 14.19: Three regions of the pharynx

Plate 14.3: Interior of the pharynx (posterior view, the pharynx opened from behind)


Pharyngeal tonsil
Middle nasal concha
Nasal septum (posterior edge)
Inferior nasal concha
Cut edge of pharynx
Uvula
Palatopharyngeal arch
Palatine tonsil
Epiglottis
Aryepiglottic fold
Piriform fossa
Laryngeal inlet
Nasopharynx
Soft palate
Cavity of mouth
Base of tongue
Oropharynx
Cuneiform tubercle
Corniculate tubercle
Laryngopharynx
Post-cricoid area
Oesophagus

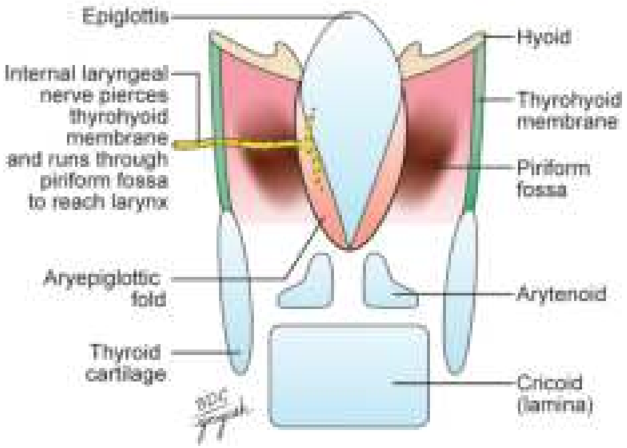

Epiglottis
Internal laryngeal nerve pierces thyrohyoid membrane and runs through piriform fossa to reach larynx
Aryepiglottic fold
Thyroid cartilage
Hyoid
Thyrohyoid membrane
Piriform fossa
Arytenoid
Cricoid (lamina)

Fig. 14.20: Posterior view of the piriform fossa after removal of the tongue: Internal laryngeal nerve is shown only on left side

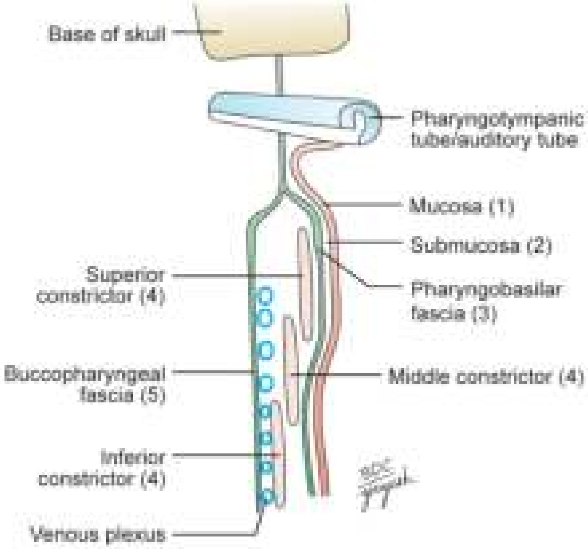

Base of skull
Pharyngotympanic tube/auditory tube
Mucosa (1)
Submucosa (2)
Pharyngobasilar fascia (3)
Superior constrictor (4)
Buccopharyngeal fascia (5)
Middle constrictor (4)
Inferior constrictor (4)
Venous plexus

Fig. 14.21: Structure of the pharynx

The three constrictors are so arranged that the inferior overlaps middle which in turn overlaps the superior. The fibres of the superior constrictor reach the base of skull posteriorly, in the middle line. On the sides, however, there is a gap between the base of the skull and the upper edge of the superior constrictor. This gap is closed by the ***pharyngobasilar fascia*** which is thickened in this situation (Fig. 14.21). The lower edge of the inferior constrictor becomes continuous with the circular muscle of the oesophagus. These muscles develop from IV arch.

Longitudinal Muscle Coat

The pharynx has three muscles that run longitudinally (Fig. 14.23, Flowchart 14.5, Table 14.6):

1. Stylopharyngeus
2. Palatopharyngeus
3. Salpingopharyngeus

Plate 14.4: Constrictors of the pharynx

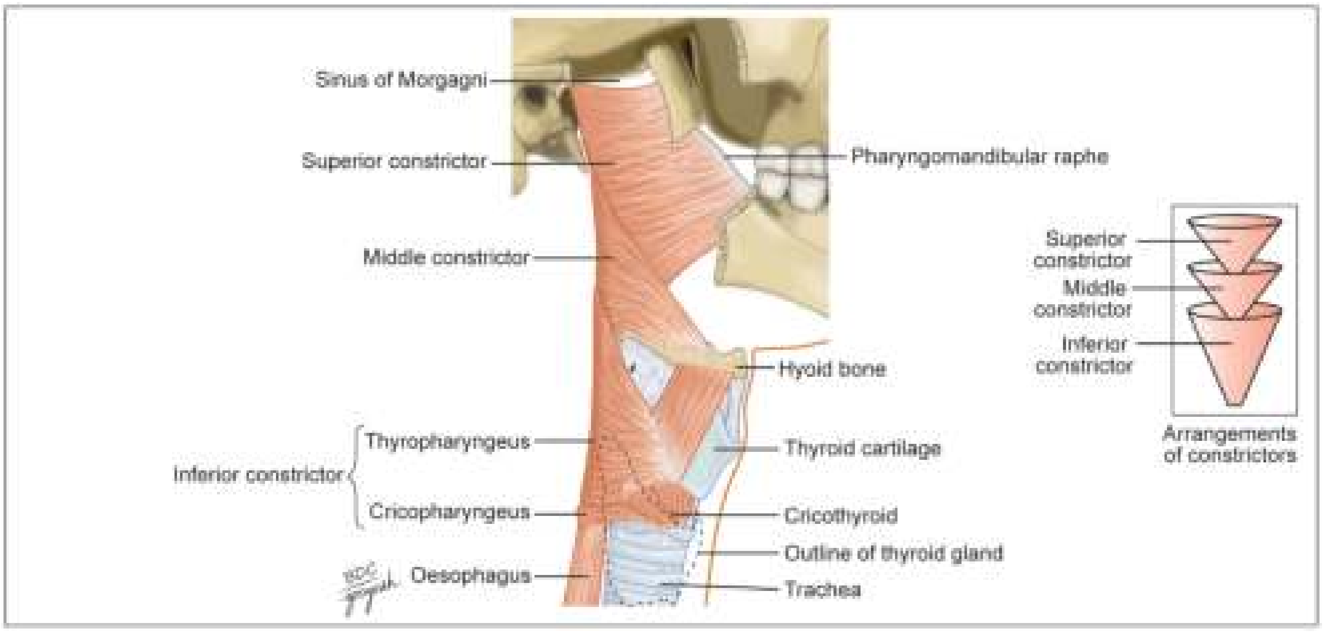

Sinus of Morgagni
Superior constrictor
Middle constrictor
Pharyngomandibular raphe
Superior constrictor
Middle constrictor
Inferior constrictor
Hyoid bone
Inferior constrictor
Thyropharyngeus
Cricopharyngeus
Thyroid cartilage
Arrangements of constrictors
Cricothyroid
Outline of thyroid gland
Oesophagus
Trachea

TABLE 14.5: Constrictor muscles of pharynx

Muscle	***Origin***	***Insertion***
Superior constrictor	Pterygoid hamulus Pterygomandibular raphe Medial surface of mandible at the posterior end of mylohyoid line Side of posterior part of the tongue	Pharyngeal tubercle on the base of skull Median fibrous raphe
Middle constrictor	Lower part of stylohyoid ligament Lesser cornua of hyoid bone Upper border of greater cornua of hyoid bone	Median fibrous raphe
Inferior constrictor: Two parts—		
1. Thyropharyngeus	Oblique line on lamina of thyroid cartilage Tendinous band between inferior tubercle of thyroid cartilage and cricoid cartilage	Median fibrous raphe
2. Cricopharyngeus	Cricoid cartilage	Median fibrous raphe

TABLE 14.6: Longitudinal muscles of pharynx

Muscle	***Origin***	***Insertion***	***Nerve supply***
Stylopharyngeus	Styloid process	Posterior border of lamina of thyroid cartilage	Glossopharyngeal nerve
Palatopharyngeus	Arises by two fasciculi (anterior and posterior) from upper surface of palatine aponeurosis	Posterior border of lamina of thyroid cartilage Few fibres run posteriorly to form *Passavant's ridge*	Cranial root of 11th cranial nerve
Salpingopharyngeus	Lower part of the cartilage of auditory tube	Posterior border of lamina of thyroid cartilage	Cranial root of 11th cranial nerve

Note: *Action of longitudinal muscles of pharynx*: Elevate the larynx and shorten the pharynx during deglutition.

All these muscles are inserted on the *posterior border of lamina of thyroid cartilage*. These muscles elevate the larynx and shorten the pharynx during swallowing.

Structures in between Pharyngeal Muscles (Fig. 14.24)

1. The *large gap between the upper concave border of the superior constrictor and the base of the skull* is semilunar and is known as the ***sinus of Morgagni***. It is closed by the upper strong part of the pharyngobasilar fascia. The structures passing through this gap are (Fig. 14.24):
   a. Auditory tube
   b. Levator veli palatini muscle
   c. Ascending palatine artery
   d. Palatine branch of ascending pharyngeal artery.

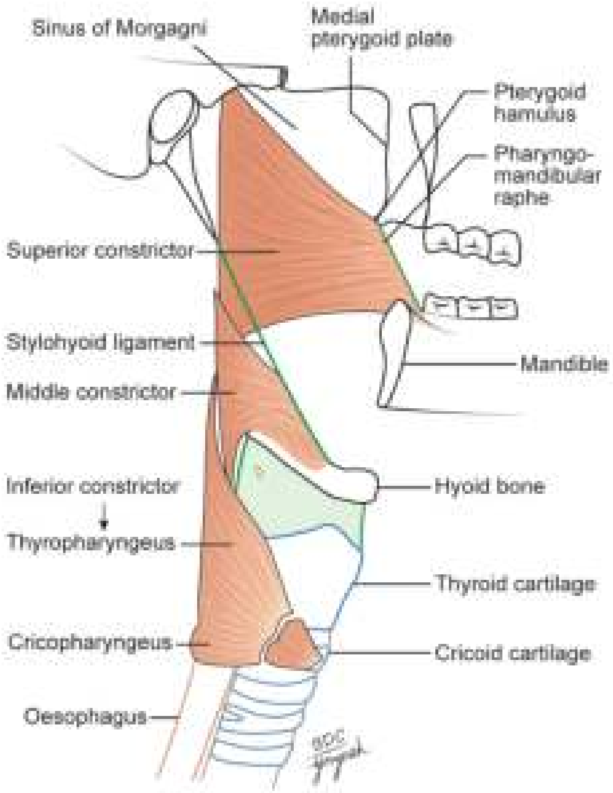

Sinus of Morgagni
Medial pterygoid plate
Pterygoid hamulus
Pharyngo-mandibular raphe
Superior constrictor
Stylohyoid ligament
Mandible
Middle constrictor
Inferior constrictor
Hyoid bone
Thyropharyngeus
Thyroid cartilage
Cricopharyngeus
Cricoid cartilage
Oesophagus

Fig. 14.22: Constrictors of the pharynx

Flowchart 14.4: Constrictor muscles of pharynx

Constrictor muscles of pharynx

Muscle	***Origin***	***Insertion***
Superior	Pterygoid hamulus Pterygomandibular raphe Mandible at posterior end of mylohyoid line, side of tongue	Pharyngeal tubercle Median raphe
Middle	Lower part of stylohyoid ligament Lesser cornua, upper border of greater cornua of hyoid bone	Median raphe
Inferior A. Thyro-pharyngeus	Oblique line on lamina of thyroid cartilage	Median raphe
B. Crico-pharyngeus	Cricoid cartilage	Median raphe

Nerve supply: Cranial root of accessory nerve

2. The structures passing through the *gap between the superior and middle constrictors* are:
   a. Stylopharyngeus muscle
   b. Glossopharyngeal nerve.
3. The structures passing through the *gap between the middle and inferior constrictors are:*
   a. Internal laryngeal nerve
   b. Superior laryngeal vessels
4. The structures passing through the *gap between the lower border of the inferior constrictor and the oesophagus* are:
   a. Recurrent laryngeal nerve
   b. Inferior laryngeal vessels.

Flowchart 14.5: Longitudinal muscles of pharynx

Longitudinal muscles of pharynx

Elevate, shorten the pharynx

Muscle	***Origin***	***Insertion***
Stylopharyngeus	Styloid process	Posterior border of lamina of thyroid cartilage
Palatopharyngeus	Upper surface of palatine aponeurosis	
Salpingopharyngeus	Lower part of cartilage of auditory tube	

Nerve supply: Stylopharyngeus by glossopharyngeal nerve, palatopharyngeus and salpingopharyngeus by cranial root of XIth cranial nerve

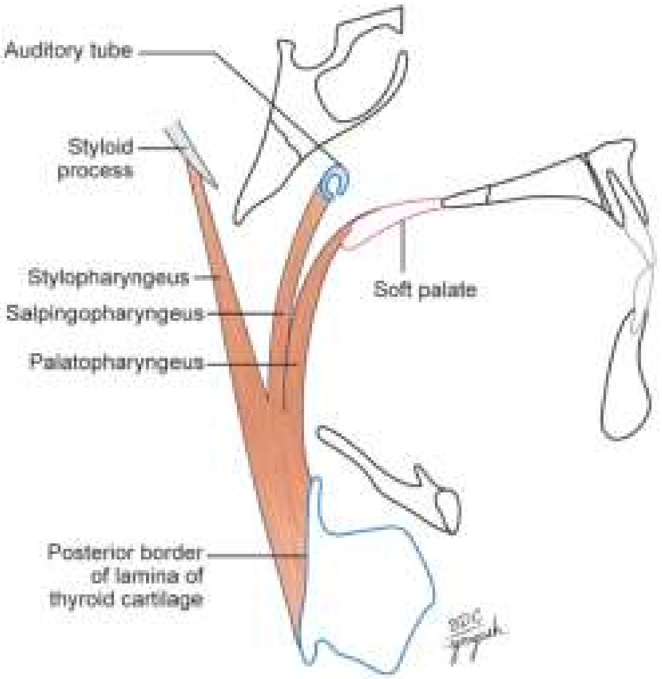

Auditory tube
Styloid process
Stylopharyngeus
Salpingopharyngeus
Palatopharyngeus
Soft palate
Posterior border of lamina of thyroid cartilage

Fig. 14.23: Longitudinal muscles of pharynx

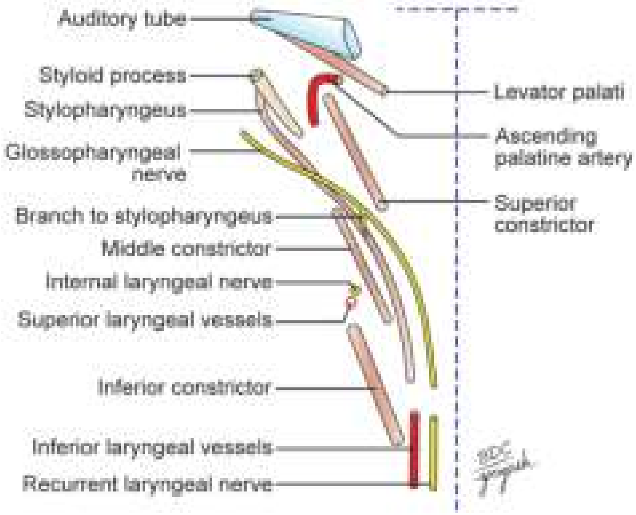

Auditory tube
Styloid process
Stylopharyngeus
Glossopharyngeal nerve
Branch to stylopharyngeus
Middle constrictor
Internal laryngeal nerve
Superior laryngeal vessels
Inferior constrictor
Inferior laryngeal vessels
Recurrent laryngeal nerve
Levator palati
Ascending palatine artery
Superior constrictor

Fig. 14.24: Schematic coronal section through the pharynx, showing the gaps between pharyngeal muscles and the structures related to them

DISSECTION

Define the attachments of middle and inferior constrictors of pharynx, and the structures situated traversing through the gaps between the three constrictor muscles. Identify structures above the superior constrictor muscle and below the inferior constrictor muscle.

Cut through the tensor veli palatini and reflect it downwards. Remove the fascia and identify the mandibular nerve again with otic ganglion medial to it. Identify the branches of the mandibular nerve. Locate the middle meningeal artery at the foramen spinosum, as it lies just posterior to mandibular nerve.

Competency:
AN36.7 Describe the clinical significance of Killian's dehiscence.

Killian's Dehiscence

Zenker's diverticulum (*hypopharyngeal diverticulum*) or pharyngeal pouch is a diverticulum of pharyngeal mucosa, just above the cricopharyngeus muscle. *Killian dehiscence* is a weak posterior part of the pharyngeal wall that lies between cricopharyngeus and thyropharyngeus parts of the inferior constrictor of pharynx (Figs 14.25a and b and Flowchart 14.6).

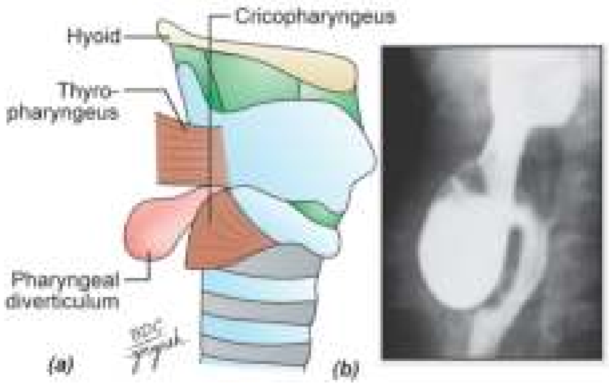
In case of the excessive pressure within the lower part of pharynx, the mucosa of the pharyngeal wall balloon out through the Killian dehiscence to form Zenker's diverticulum. It may result due to neuromuscular incoordination or spasm of cricopharyngeus muscle. It occurs because the two parts of the inferior constrictor have different nerve supplies. The propulsive thyropharyngeus is supplied by the pharyngeal plexus and the sphincteric cricopharyngeus is supplied by the recurrent laryngeal nerve. In neuromuscular incoordination, if the cricopharyngeus fails to relax when the thyropharyngeus contracts, the bolus of food is pushed backward and tends to produce a diverticulum.

Signs and symptoms of Zenker's diverticulum:

1. Asymptomatic
2. Dysphagia (difficulty in swallowing)
3. Regurgitation of food
4. Cough.

It can be diagnosed using:

1. Barium swallow radiography
2. Endoscopy.


Cricopharyngeus
Hyoid
Thyro-
pharyngeus
Pharyngeal
diverticulum
(a)
(b)

Figs 14.25a and b: (a) Pharyngeal diverticulum and (b) pharyngeal diverticulum after barium swallow

Nerve Supply of Pharynx

The pharynx is supplied by the pharyngeal plexus of nerves which lies chiefly on the middle constrictor. The plexus is formed by:

1. Pharyngeal branch of the vagus carrying fibres of the cranial accessory nerve.
2. Pharyngeal branches of the glossopharyngeal nerve.
3. Pharyngeal branches of the superior cervical sympathetic ganglion.

Motor fibres are derived from the cranial accessory nerve through the branches of the vagus. They supply all muscles of pharynx, except the stylopharyngeus which is supplied by the glossopharyngeal nerve.

The inferior constrictor receives an additional supply from the external and recurrent laryngeal nerves.

Sensory fibres or general visceral afferent from the pharynx travel mostly through the glossopharyngeal nerve, and partly through the vagus. However, the nasopharynx is supplied by the maxillary nerve through the pterygopalatine ganglion; and the soft palate and tonsil by the lesser palatine and glossopharyngeal nerves.

Taste sensations from the vallecula and epiglottic area pass through the internal laryngeal branch of the vagus.

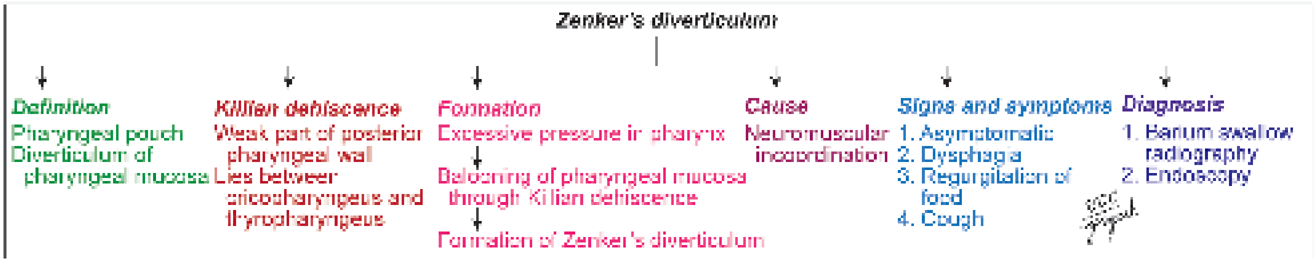
The parasympathetic ***secretomotor fibres*** to the pharynx are derived from the lesser palatine branches of the pterygopalatine ganglion.

Blood Supply of Pharynx

The pharynx is supplied by:

1. Ascending pharyngeal branch of the external carotid.

Flowchart 14.6: Killian dehiscence Zenker's diverticulum


Zenker's diverticulum
Definition
Pharyngeal pouch
Diverticulum of pharyngeal mucosa
Killian dehiscence
Weak part of posterior pharyngeal wall
Lies between cricopharyngeus and thyropharyngeus
Formation
Excessive pressure in pharynx
Balooning of pharyngeal mucosa through Killian dehiscence
Formation of Zenker's diverticulum
Cause
Neuromuscular incoordination
Signs and symptoms
1. Asymptomatic
2. Dysphagia
3. Regurgitation of food
4. Cough
Diagnosis
1. Barium swallow radiography
2. Endoscopy

2. Ascending palatine and tonsillar branches of the facial artery.
3. Dorsal lingual branches of the lingual artery.
4. Greater palatine, pharyngeal and pterygoid branches of the maxillary artery.

The veins form a plexus on the posterolateral aspect of the pharynx. The plexus receives blood from the pharynx, the soft palate and the prevertebral region. It drains into the internal jugular and facial veins.

Lymphatic Drainage of Pharynx

Lymph from the pharynx drains into the retropharyngeal and deep cervical lymph nodes.

Deglutition (Swallowing)

Swallowing of food occurs in three stages described below. Muscles of pharynx act during swallowing.

First Stage

1. This stage is voluntary in character.
2. The anterior part of the tongue is raised and pressed against the hard palate by the intrinsic muscles of the tongue, especially the superior longitudinal and transverse muscles. The movement takes place from anterior to the posterior side. This pushes the food bolus (Greek *lump*) into the posterior part of the oral cavity.
3. The soft palate closes down onto the back of the tongue, and helps to form the bolus.
4. Next, the hyoid bone is moved upwards and forwards by the suprahyoid muscles. The posterior part of the tongue is elevated upwards and backwards by the styloglossi; and the palatoglossal arches are approximated by the palatoglossi. This pushes the bolus through the oropharyngeal isthmus to the oropharynx, and the second stage begins.

Second Stage

1. It is involuntary in character. During this stage, the food is pushed from the oropharynx to the lower part of the laryngopharynx.
2. The nasopharyngeal isthmus is closed by elevation of the soft palate by levator veli palatini and tensor veli palatini and by approximation to its the posterior pharyngeal wall (ridge of Passavant). This prevents the food bolus from entering the nose.
3. The inlet of larynx is closed by approximation of the aryepiglottic folds by aryepiglottic and oblique arytenoid. This prevents the food bolus from entering the larynx.
4. Next, the larynx and pharynx are elevated behind the hyoid bone by the longitudinal muscles of the pharynx. Then the bolus is pushed down over the posterior surface of the epiglottis, the closed inlet of the larynx and the posterior surface of the arytenoid cartilages, by gravity, and by contraction of the superior and middle constrictors and the palatopharyngeus.

Third Stage

1. This is also involuntary in character. In this stage, food passes from the lower part of the pharynx to the oesophagus.
2. This is brought about by the inferior constrictors of the pharynx.

Development of Pharynx

The primitive gut extends from the buccopharyngeal membrane cranially, to the cloacal membrane caudally. It is divided into four parts—the pharynx, the foregut, the midgut and the hindgut. The pharynx extends from buccopharyngeal membrane to the tracheobronchial diverticulum. It is divided into upper part, the nasopharynx; middle part, the oropharynx; and the lower part, the laryngopharynx.

Competency:
AN36.4 Describe the components and functions of Waldeyer's lymphatic ring.

Waldeyer's Lymphatic Ring

In relation to the naso-oropharyngeal isthmus, there are several aggregations of lymphoid tissue that constitute Waldeyer's lymphatic ring (Fig. 14.26). The most important aggregations are the right and left palatine tonsils usually referred to simply as the tonsils. Posteriorly and above, there is the nasopharyngeal tonsil; laterally and above, there are the tubal tonsils, and inferiorly, there is the lingual tonsil over the posterior part of the dorsum of the tongue. [*Mnemonics: Tonsils: The four types "PPLT (people) have tonsils"*: **P**haryngeal, **P**alatine, **L**ingual, **T**ubal].

CLINICAL ANATOMY

1. Hypertrophy or enlargement of the nasopharyngeal tonsil or adenoids may obstruct the posterior nasal aperture and may interfere with nasal respiration and speech leading to mouth breathing. These tonsils usually regress by puberty.
2. Hypertrophy of the tubal tonsil may occlude the auditory or pharyngotympanic tube leading to middle ear problems.

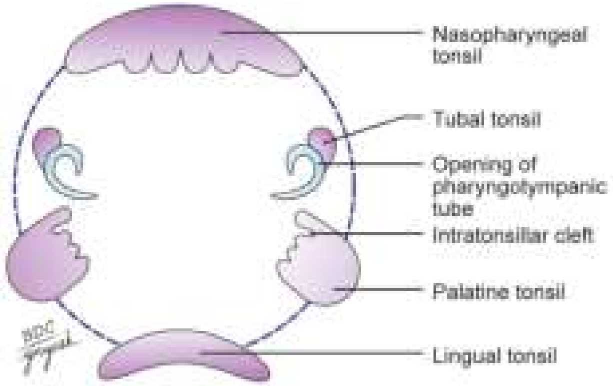


Fig. 14.26: Waldeyer's lymphatic ring

Competencies:

AN36.2 Describe the (1) morphology, relations, blood supply and applied anatomy of palatine tonsil, (2) composition of soft palate.

AN40.2 Describe and demonstrate the boundaries, contents, relations and functional anatomy of middle ear and auditory tube.

PALATINE TONSIL (THE TONSIL)

The palatine tonsil (Latin *swelling*) occupies the ***tonsillar sinus*** or ***fossa*** between the palatoglossal and palatopharyngeal arches (Fig. 14.27 and Flowchart 14.7). It can be seen through the mouth.

Features

The tonsil is almond-shaped. It has two surfaces—medial and lateral; two borders—anterior and posterior; and two poles—upper and lower.

1. ***Medial surface*** is covered by stratified squamous epithelium continuous with that of the mouth. This surface has 12 to 15 crypts. The largest of these is called the ***intratonsillar cleft***.
2. ***Lateral surface*** is covered by a sheet of fascia which forms the hemicapsule of the tonsil. The capsule is an extension of the pharyngobasilar fascia. It is only loosely attached to the muscular wall of the pharynx, formed here by the superior constrictor and by the styloglossus, but anteroinferiorly the capsule is firmly adherent to the side of the tongue (suspensory ligament of tonsil) just in front of the insertion of the palatoglossus and the palatopharyngeus muscle. This firm attachment keeps the tonsil in place during swallowing.

   The ***bed of the tonsil*** is formed from within outwards by:
   a. Pharyngobasilar fascia
   b. Superior constrictor and palatopharyngeus muscles
   c. Buccopharyngeal fascia
   d. In the lower part, the styloglossus
   e. Glossopharyngeal nerve.

   Still more laterally, there is the facial artery with its tonsillar and ascending palatine branches. The

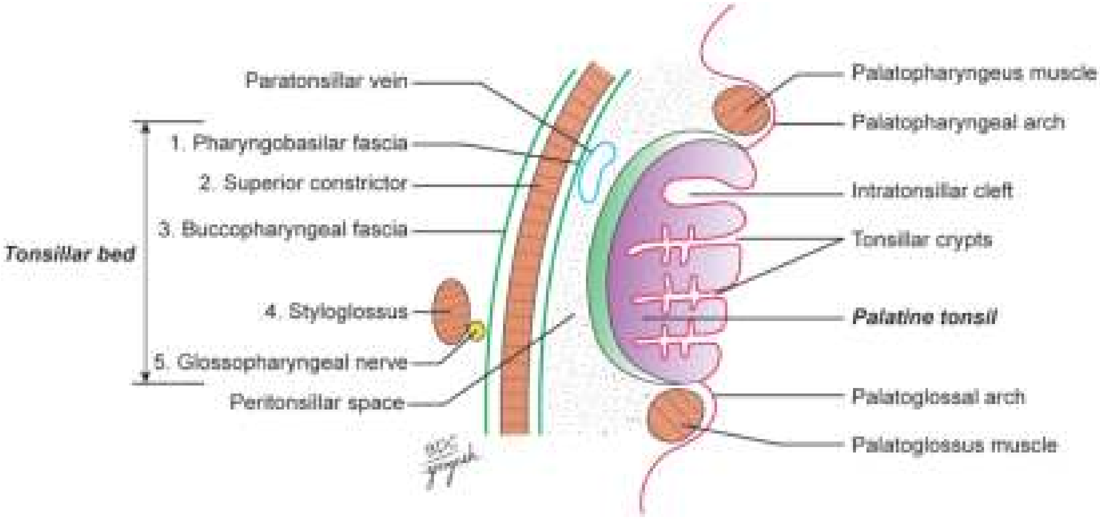
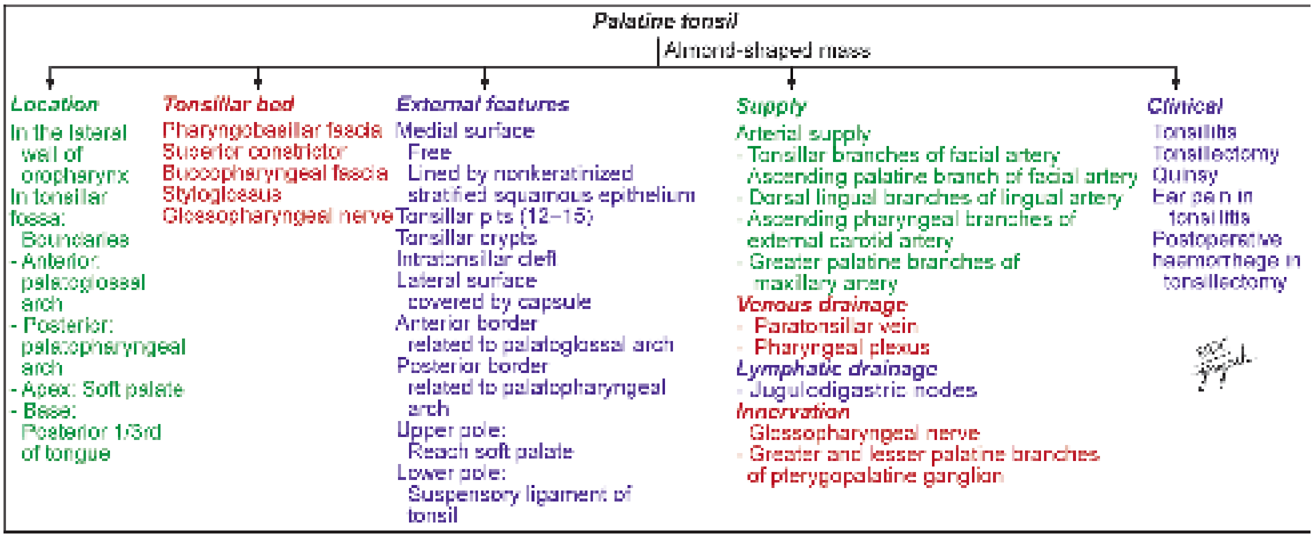

Paratonsillar vein
1. Pharyngobasilar fascia
2. Superior constrictor
3. Buccopharyngeal fascia
Tonsillar bed
4. Styloglossus
5. Glossopharyngeal nerve
Peritonsillar space
Palatopharyngeus muscle
Palatopharyngeal arch
Intratonsillar cleft
Tonsillar crypts
Palatine tonsil
Palatoglossal arch
Palatoglossus muscle

Fig. 14.27: Horizontal section through the tonsil showing its deep relations

Flowchart 14.7: Palatine tonsil


Palatine tonsil
Almond-shaped mass
Location
In the lateral wall of oropharynx
In tonsillar fossa:
Boundaries
- Anterior: palatoglossal arch
- Posterior: palatopharyngeal arch
- Apex: Soft palate
- Base: Posterior 1/3rd of tongue
Tonsillar bed
Pharyngobasilar fascia
Superior constrictor
Buccopharyngeal fascia
Styloglossus
Glossopharyngeal nerve
External features
Medial surface
Free
Lined by nonkeratinized stratified squamous epithelium
Tonsillar pits (12–15)
Tonsillar crypts
Intratonsillar cleft
Lateral surface
covered by capsule
Anterior border
related to palatoglossal arch
Posterior border
related to palatopharyngeal arch
Upper pole:
Reach soft palate
Lower pole:
Suspensory ligament of tonsil
Supply
Arterial supply
- Tonsillar branches of facial artery
Ascending palatine branch of facial artery
- Dorsal lingual branches of lingual artery
- Ascending pharyngeal branches of external carotid artery
- Greater palatine branches of maxillary artery
Venous drainage
- Paratonsillar vein
- Pharyngeal plexus
Lymphatic drainage
- Jugulodigastric nodes
Innervation
Glossopharyngeal nerve
- Greater and lesser palatine branches of pterygopalatine ganglion
Clinical
Tonsillitis
Tonsillectomy
Quinsy
Ear pain in tonsillitis
Postoperative haemorrhage in tonsillectomy

internal carotid artery is 2.5 cm posterolateral to the tonsil.

3. ***Anterior border*** is related to the palatoglossal arch with its muscle.
4. ***Posterior border*** is related to the palatopharyngeal arch with its muscle.
5. ***Upper pole*** is related to the soft palate, and the *lower pole*, to the tongue.
6. ***Plica triangularis*** is a triangular vestigial fold of mucous membrane covering the anteroinferior part of the tonsil.
7. ***Plica semilunaris*** is a similar semilunar fold that may cross the upper part of the tonsillar sinus.
8. ***Intratonsillar cleft*** is the largest crypt of the tonsil. It is present in its upper part. It is sometimes wrongly named the supratonsillar fossa. The mouth of cleft is semilunar in shape and parallel to dorsum of tongue. It represents the internal opening of the second pharyngeal pouch. A peritonsillar abscess or quinsy often begins in this cleft.

Arterial Supply of Tonsil

1. *Main source*: Tonsillar branch of facial artery (Fig. 14.28).
2. *Additional sources*:
   a. Ascending palatine branch of facial artery
   b. Dorsal lingual branches of the lingual artery
   c. Ascending pharyngeal branch of the external carotid artery
   d. Greater palatine branch of the maxillary artery.

Venous Drainage

One or more paratonsillar veins leave the lower part of deep surface of the tonsil, pierce the superior constrictor, and join the palatine, pharyngeal, or facial veins.

Note: The tonsillar artery enters the tonsil by piercing the superior constrictor just behind the firm attachment.

The palatine vein or external palatine or ***paratonsillar vein*** descends from the palate in the loose areolar tissue on the lateral surface of the capsule, and crosses the tonsil before piercing the wall of the pharynx. The vein may be injured during removal of the tonsil or tonsillectomy.

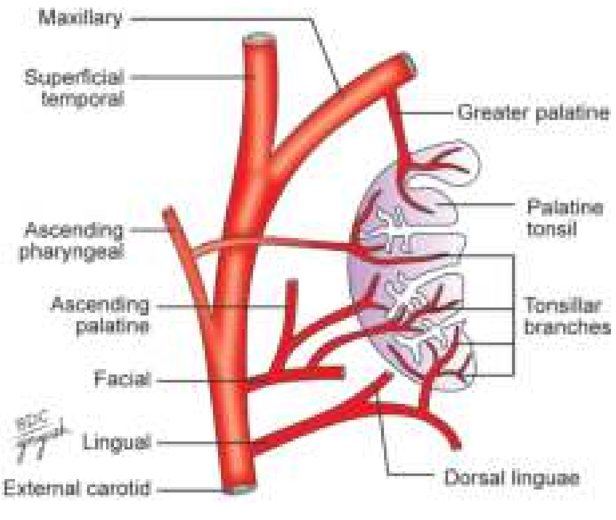


Fig. 14.28: Arterial supply of palatine tonsil

Lymphatic Drainage

Lymphatics pass to *jugulodigastric nodes*. There are no afferent lymphatics to the tonsil.

Nerve Supply

1. Glossopharyngeal nerve.
2. Greater and lesser palatine nerves from the pterygopalatine ganglion.

Competencies:

AN43.2 Identify, describe and draw the microanatomy of pituitary gland, thyroid, parathyroid gland, tongue, salivary glands, tonsil, cornea, retina.

AN36.6 Describe the anatomical basis of tonsillitis, tonsillectomy, adenoids and peritonsillar abscess. Microanatomy of tonsil is described here. For the other tissues please see respective chapters.

Histology of Tonsil

A section of palatine tonsil shows (Plate 14.5):

1. Lining epithelium
2. Tonsillar crypts
3. Lymphatic follicles.

The oral surface of the palatine tonsil is covered by nonkeratinized stratified squamous epithelium. The epithelium invaginates internal surface of tonsil and forms tonsillar crypts. Tonsillar crypts are lined by nonkeratinized stratified squamous epithelium. Epithelium and even the lumen of crypts may show invaginated lymphocytes. It is difficult to find boundary between epithelium and lymphoid tissue.

Laterally, tonsil is bounded by connective tissue capsule and has some efferent lymphatic vessels. Just beneath epithelium, palatine tonsil shows dense aggregation of lymphatic follicles. Lymphatic follicles are supported by meshwork of reticular fibres.

Development of Tonsil

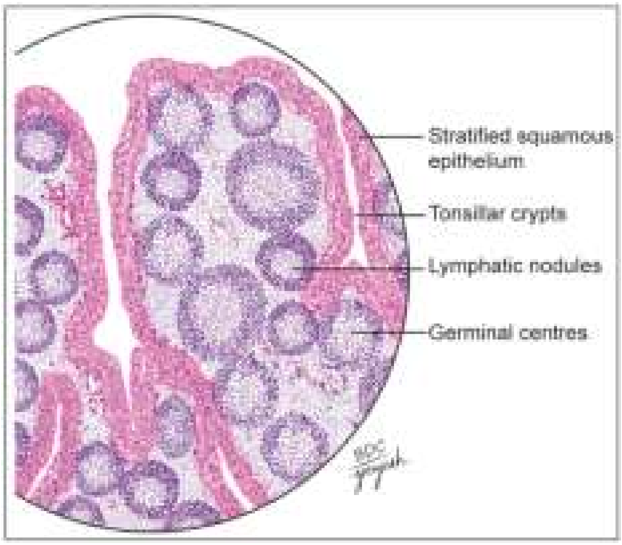
Palatine tonsil develops from two sources:

1. Endoderm of second pharyngeal pouch
2. Mesoderm (lymphocytes).

Stages of Development

1. During the 3rd month of development, ventral part of the 2nd pouch proliferates outwards in surrounding mesoderm as several solid cords called tonsillar buds.
2. On degeneration of central cells, tonsillar buds cannulate to form hollow tonsillar crypts.
3. During 3rd to 5th month, lymphocytes aggregate on the mesoderm that surrounds crypts and forms lymphatic follicles.
4. Mesodermal cells condense to form a capsule of the tonsil. Lymphocyte proliferates and forms pharyngeal tonsillar bulging. The remnant of the pouch is represented by an intratonsillar cleft and tonsillar fossa.

Plate 14.5: Histology of palatine tonsil



CLINICAL ANATOMY

1. The tonsils are large in children. They retrogress after puberty.
2. ***Tonsillitis***: The tonsils are frequently sites of infection, especially in children. Infection may spread to surrounding tissue forming a peritonsillar abscess.
3. Enlarged and infected tonsils often require surgical removal. The operation is called ***tonsillectomy***. A knowledge of the relationship of the tonsil is of importance to the surgeon.
4. Tonsillectomy is usually done by the ***guillotine method***. Haemorrhage after tonsillectomy is checked by removal of clot from the raw tonsillar bed. This is to be compared with the method for checking postpartum haemorrhage from the uterus. These are the only two organs in the body where bleeding is checked by removal of clots. In other parts of the body, clot formation is encouraged.
5. Tonsillitis may cause ***referred pain*** in the ear as glossopharyngeal nerve supplies both these areas.
6. Suppuration in the peritonsillar area is called ***quinsy***. A peritonsillar abscess is drained by making an incision in the most prominent point of the abscess.
7. Tonsils are often sites of a septic focus. Such a focus can lead to serious disease like pulmonary tuberculosis, meningitis, etc. and is often the cause of general ill health.

PHARYNGOTYMPANIC TUBE

Auditory tube is also known as the pharyngotympanic tube or the eustachian tube.

The auditory tube is a trumpet-shaped channel that connects the middle ear cavity with the nasopharynx (Figs 14.29a and b).

Measurements

It is about 4 cm long, and is directed downwards, forwards and medially. It forms an angle of 45° with the sagittal plane and 30° with the horizontal plane.

Parts

The tube is divided into bony and cartilaginous parts.

Bony Part

The bony part forms the posterior and lateral one-third of the tube. It is 12 mm long, and lies in the petrous temporal bone near the tympanic plate. Its lateral end is wide and opens on the anterior wall of the middle ear cavity. The medial end is narrow (isthmus) and is jagged for attachment of the cartilaginous part. The lumen of the tube is oblong being widest from side-toside.

Relations

1. *Superior:* Canal for the tensor tympani.
2. *Medial:* Carotid canal.
3. *Lateral:* Chorda tympani, spine of sphenoid, auriculotemporal nerve and the temporomandibular joint.

Cartilaginous Part

The cartilaginous part forms the anterior and medial two-thirds of the tube. It is 25 mm long, and lies in the sulcus tubae, a groove between the greater wing of the sphenoid and the apex of the petrous temporal. It is made up of a triangular plate of cartilage which is curled to form the superior and medial walls of the tube. The lateral wall and floor are completed by a fibrous membrane. The apex of the plate is attached to the medial end of the bony part. The base is free and forms the tubal elevation in the nasopharynx.

Relations

1. *Anterolaterally:* Tensor veli palatini, mandibular nerve and its branches, otic ganglion, chorda tympani, middle meningeal artery and medial pterygoid plate.
2. *Posteromedially:* Petrous temporal and levator veli palatini.
3. The levator veli palatini is attached to its inferior surface, and the salpingopharyngeus to lower part near the pharyngeal opening.

Vascular Supply

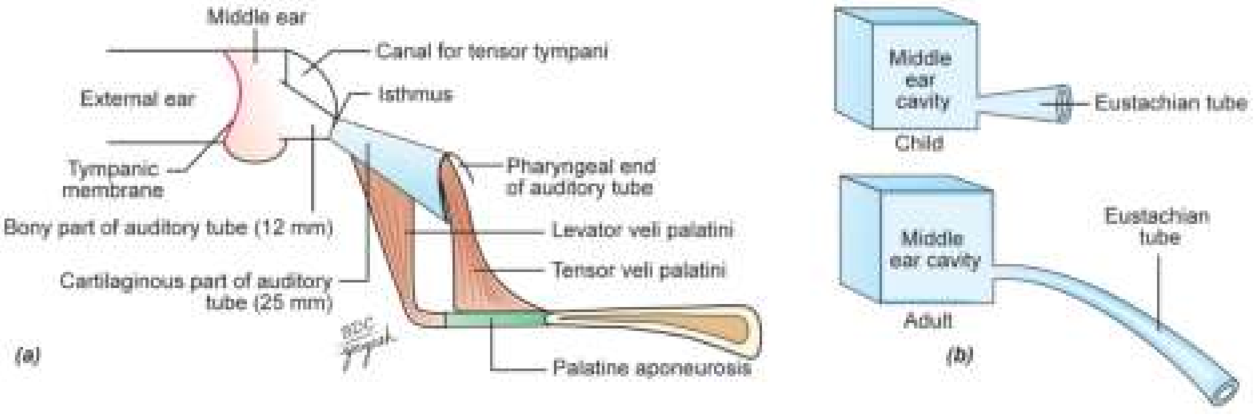
The arterial supply of the tube is derived from the ascending pharyngeal and middle meningeal arteries and the artery of the pterygoid canal. The veins drain into the pharyngeal and pterygoid plexuses of veins. Lymphatics pass to the retropharyngeal nodes.

Nerve Supply

1. At the ostium, by the pharyngeal branch of the pterygopalatine ganglion suspended by the maxillary nerve.
2. Cartilaginous part, by the nervus spinosus branch of mandibular nerve.
3. Bony part, by the tympanic plexus formed by glossopharyngeal nerve.

Functions

1. The tube provides a communication of the middle ear cavity with the exterior, thus ensuring equal air pressure on both sides of the tympanic membrane.
2. The tube is usually closed. It opens during swallowing, yawning and sneezing, by the actions of the tensor and levator veli palatini muscles.


Middle ear
Canal for tensor tympani
External ear
Isthmus
Tympanic membrane
Pharyngeal end of auditory tube
Bony part of auditory tube (12 mm)
Levator veli palatini
Cartilaginous part of auditory tube (25 mm)
Tensor veli palatini
(a)
Palatine aponeurosis
Middle ear cavity
Eustachian tube
Child
Eustachian tube
Middle ear cavity
Adult
(b)

Figs 14.29a and b: (a) Scheme showing anatomy of auditory tube and external auditory meatus and (b) differences in Eustachian tube in an adult and a child

CLINICAL ANATOMY

- Infections may pass from the throat to the middle ear through the auditory tube. This is more common in children because the tube is shorter, wider and straighter in them.
- Inflammation of the auditory tube (Eustachian catarrh) is often secondary to an attack of common cold, or of sore throat. This causes pain in the ear which is aggravated by swallowing, due to blockage of the tube. Pain is relieved by instillation of decongestant drops in the nose, which help to open the ostium. The ostium is commonly blocked in children by enlargement of the tubal tonsil.

Video 3.14 **Pharynx:** Introduction, Muscles of pharynx, Palate

Facts to Remember

- Upper teeth are supplied by branches of maxillary nerve.
- Lower teeth are supplied by branches of mandibular nerve.
- All the 3 constrictors and 2 longitudinal muscles of pharynx are supplied by vagoaccessory complex, only stylopharyngeus is supplied by IX nerve.
- All the muscles of soft palate are supplied by vagoaccessory complex except tensor veli palatini, supplied by V3 nerve.
- Tonsils have only efferent lymph vessels but no afferent lymph vessel.
- Killian's dehiscence is a potential gap between thyropharyngeus and cricopharyngeus.
- Waldeyer's ring consists of lingual tonsil, palatine tonsils, tubal tonsils and nasopharyngeal tonsils.
- Tonsillar branch of facial artery is the main artery of the palatine tonsil.
- Common source of bleeding after tonsillectomy is paratonsillar vein.
- Quinsy is the chronic infection of peritonsillar space.

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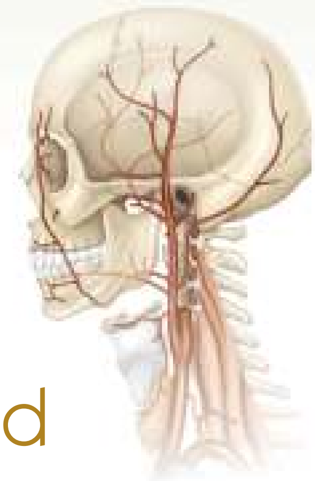
1. Molecular regulation of tooth development
2. Morphology of palatopharyngeus
3. Further reading
4. Viva voce questions



Chapter 15

Nose, Paranasal Sinuses and Pterygopalatine Fossa

NOSE

The nose performs two functions. It is a respiratory passage. It is also the organ of smell. The receptors for smell are placed in the upper one-third of the nasal cavity. This part is lined by olfactory mucosa. The rest of the nasal cavity is lined by respiratory mucosa. The respiratory mucosa is highly vascular and warms the inspired air.

For descriptive purposes, the nose is divided into two main parts, the external nose and nasal cavity.

EXTERNAL NOSE

The external nose presents the following features:

1. *Tip* or apex is lower free end.
2. *Root* or bridge is an upper narrow part which is continuous with the forehead.
3. *Dorsum* is a rounded border between the tip and root.
4. *Nostrils* or nares are two piriform apertures at the lower ends of the nose.
5. *Ala* is a lower flared part on the side of nose.
6. *Nasal septum* separates the nostrils.

The external nose has a skeletal framework that is partly bony and partly cartilaginous. The bones are the nasal bones, which form the bridge of the nose, and the frontal processes of the maxillae. The cartilages are the superior and inferior nasal cartilages, the septal cartilage, and small alar cartilages (Fig. 15.1).

The ***skin over the external nose*** is supplied by the external nasal, infratrochlear and infraorbital nerves.

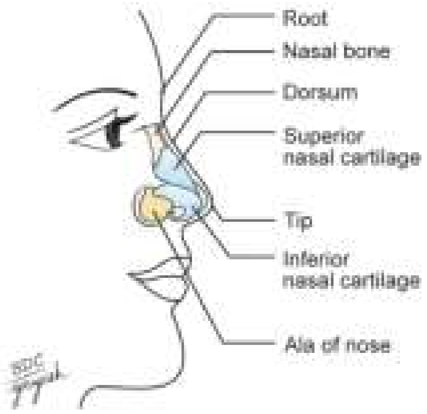

Root
Nasal bone
Dorsum
Superior nasal cartilage
Tip
Inferior nasal cartilage
Ala of nose

Fig. 15.1: Skeleton of the external nose

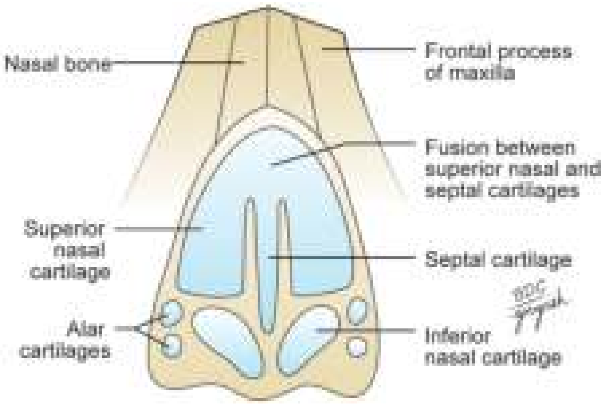

Nasal bone
Frontal process of maxilla
Fusion between superior nasal and septal cartilages
Superior nasal cartilage
Septal cartilage
Alar cartilages
Inferior nasal cartilage

Fig. 15.2: Osseocartilaginous framework of the external nose

NASAL CAVITY

The nasal cavity extends from the external nares or nostrils to the posterior nasal apertures, and is subdivided into right and left halves by the nasal septum (Figs 15.2 and 15.3).

Divisions

Each cavity is divided into two parts:

1. *Vestibule*: It is a small anterior part lined by skin.
2. *Nasal cavity proper*: It is large posterosuperior part lined by nasal mucosa.

Vestibule of Nose

The vestibule of nose is a small anteroinferior part of nasal cavity. It is lined by skin which contains sebaceous glands and hairs. ***Vibrissae*** are stiff interlacing hairs of the vestibule. ***Limen nasi*** is a ridge between the vestibule and the nasal cavity proper. ***Columella*** is a median lower part of the nose separating the right and left vestibules of nose.

Nasal Cavity Proper

Boundaries

Each half has a roof, a floor, and medial and lateral walls. Each half measures about 5 cm in height, 5–7 cm

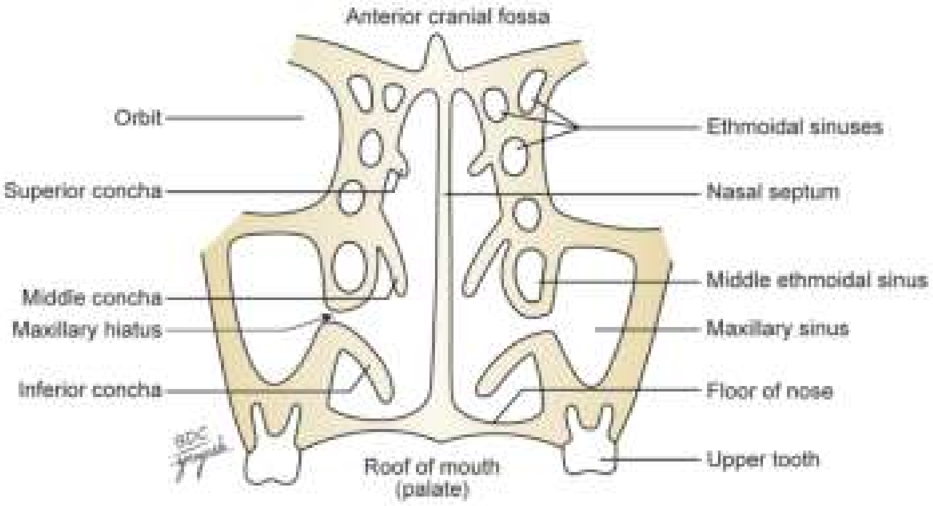

Anterior cranial fossa
Orbit
Superior concha
Middle concha
Maxillary hiatus
Inferior concha
Ethmoidal sinuses
Nasal septum
Middle ethmoidal sinus
Maxillary sinus
Floor of nose
Upper tooth
Roof of mouth (palate)

Fig. 15.3: Coronal section through the nasal cavity and the maxillary air sinuses

in length, and 1.5 cm in width near the floor. The width near the roof is only 1–2 mm.

1. ***Roof*** is about 7 cm long and 2 mm wide. It slopes downwards, both in front and behind. The middle horizontal part is formed by the cribriform plate of the ethmoid. The anterior slope is formed by the nasal part of the frontal bone, nasal bone, and the nasal cartilages. The posterior slope is formed by the inferior surface of the body of the sphenoid bone.
2. ***Floor*** is about 5 cm long and 1.5 cm wide. It is formed by the palatine process of the maxilla and the horizontal plate of the palatine bone. It is concave from side-to-side and is slightly higher anteriorly than posteriorly (Fig. 15.2).
3. ***Medial wall*** is formed by the nasal septum.
4. ***Lateral wall*** of nose is irregular and has shelf-like projections called conchae or turbinate.

CLINICAL ANATOMY

- ***Common cold or rhinitis*** is the commonest infection of the nose. It may be infective or allergic or both. It commonly occurs during change of the seasons.
- Fracture of cribriform plate of ethmoid with tearing off of the meninges may tear the olfactory nerve rootlets (Fig. 15.4). In such cases, CSF may drip from the nasal cavity. It is called ***CSF rhinorrhoea***.

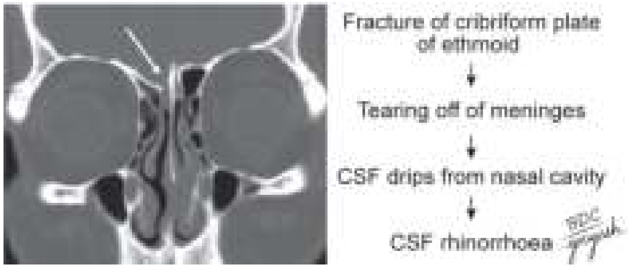

Fracture of cribriform plate of ethmoid
Tearing off of meninges
CSF drips from nasal cavity
CSF rhinorrhoea

Fig. 15.4: CSF rhinorrhoea

Competency:

AN37.1 Describe and demonstrate features of nasal septum, lateral wall of nose, their blood supply and nerve supply.

NASAL SEPTUM

The *nasal septum* is a median osseocartilaginous partition between the two halves of the nasal cavity. On each side, it is covered by mucous membrane and forms the medial wall of both nasal cavities (Plate 15.1 and Fig. 15.5, Flowchart 15.1).

Formation

Bony part is formed almost entirely by:

a. Vomer
b. Perpendicular plate of ethmoid.

Cartilaginous part is formed by:

a. Septal cartilage
b. Septal processes of the inferior nasal cartilages.

Cuticular part or lower end is formed by fibrofatty tissue covered by skin. The lower margin of the septum is called the ***columella***.

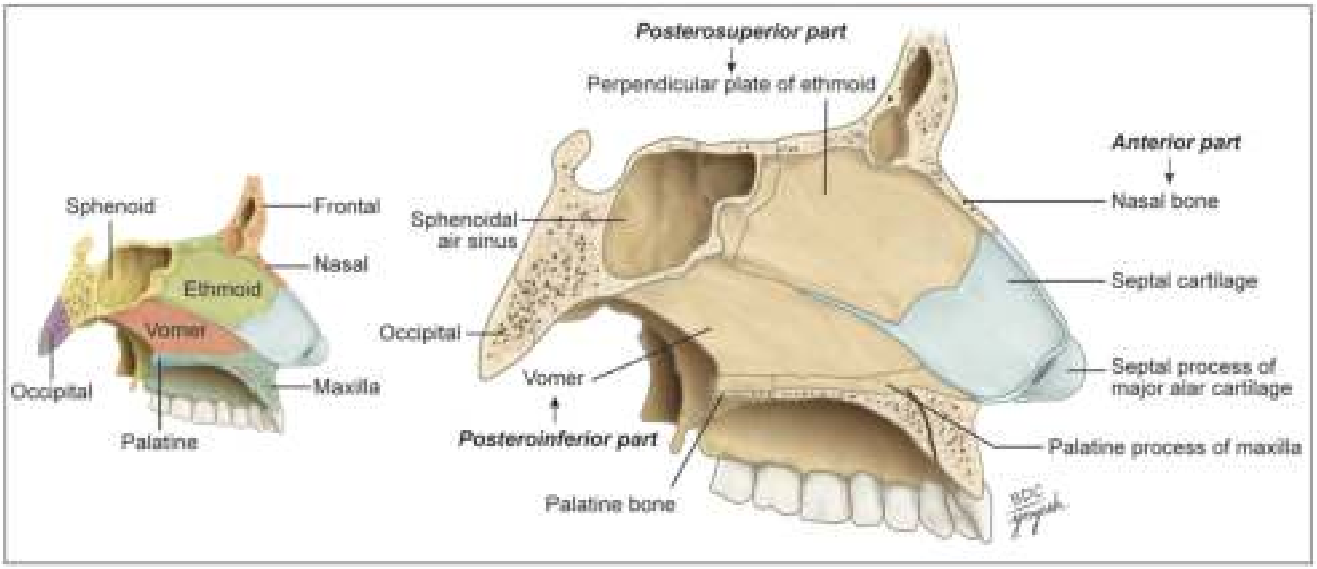
Note: The nasal septum is rarely strictly median. Its central part is usually *deflected* to one or the other side. The deflection is produced by overgrowth of one or more of the constituent parts.

Arterial Supply

1. *Anterosuperior part* is supplied by the anterior and posterior ethmoidal artery (Fig. 15.6).
2. *Anteroinferior part* is supplied by the septal branch of superior labial branch of facial artery.
3. *Posterior part* is supplied by the sphenopalatine artery. *It is the main artery*.

Kiesselbach's plexus: The anteroinferior part or vestibule of the septum contains anastomoses between all branches, e.g. the septal branch of the superior labial branch of the facial artery, sphenopalatine artery, and anterior ethmoidal artery. These form a large capillary

Plate 15.1: Formation of the nasal septum


Sphenoid
Frontal
Nasal
Ethmoid
Vomer
Occipital
Maxilla
Palatine
Posterosuperior part
Perpendicular plate of ethmoid
Sphenoidal air sinus
Occipital
Vomer
Posteroinferior part
Palatine bone
Anterior part
Nasal bone
Septal cartilage
Septal process of major alar cartilage
Palatine process of maxilla

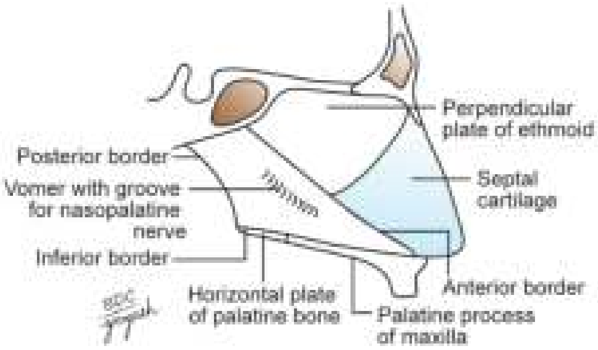

Perpendicular plate of ethmoid
Posterior border
Vomer with groove for nasopalatine nerve
Septal cartilage
Inferior border
Horizontal plate of palatine bone
Anterior border
Palatine process of maxilla

Fig. 15.5: Formation of the nasal septum

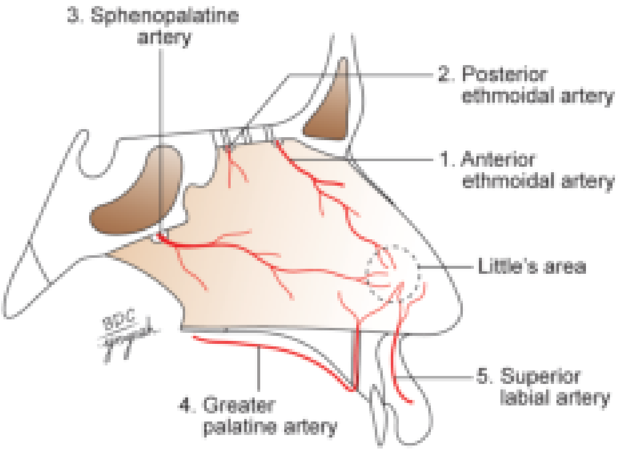
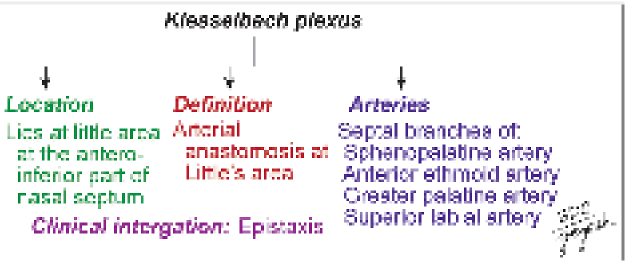

3. Sphenopalatine artery
2. Posterior ethmoidal artery
1. Anterior ethmoidal artery
Little's area
5. Superior labial artery
4. Greater palatine artery

Fig. 15.6: Arterial supply of nasal septum

Flowchart 15.1: Kiesselbach plexus


Kiesselbach plexus
Location
Lies at little area at the antero-inferior part of nasal septum
Definition
Arterial anastomosis at Little's area
Arteries
Septal branches of:
Sphenopalatine artery
Anterior ethmoid artery
Greater palatine artery
Superior labial artery
Clinical intergation: Epistaxis

network called the *Kiesselbach's plexus*. This is a common site of bleeding from the nose or epistaxis, and is known as ***Little's area***.

Venous Drainage

The veins form a plexus which is more marked in the lower part of septum or Little's area. The plexus drains anteriorly into the facial vein, and posteriorly through the sphenopalatine vein to pterygoid venous plexus.

Nerve Supply

1. ***General sensory nerves***, arising from trigeminal nerve, are distributed to whole of the septum (Fig. 15.7).
    a. The anterosuperior part of the septum is supplied by the internal nasal branches of the anterior ethmoidal nerve.
    b. The posteroinferior part is supplied by the nasopalatine branch of the pterygopalatine ganglion. *It is the main nerve.*
2. ***Special sensory nerves or olfactory*** nerves are confined to the upper part or olfactory area.

Lymphatic Drainage

Anterior half to the submandibular nodes.

Posterior half to the retropharyngeal and deep cervical nodes.

CLINICAL ANATOMY

- Sphenopalatine artery is the artery of ***epistaxis***.
- Little's area on the septum is a common site of bleeding from the nose or epistaxis (Fig. 15.5).
- Pathological ***deviation of the nasal septum*** is often responsible for repeated attacks of common cold, allergic rhinitis, sinusitis, etc. It requires surgical correction (Fig. 15.8).

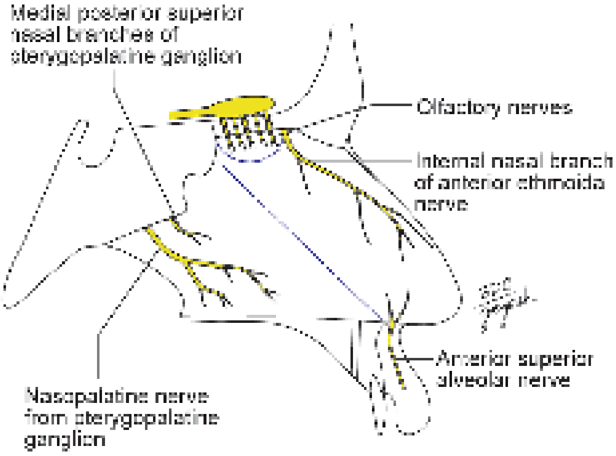

Medial posterior superior nasal branches of pterygopalatine ganglion
Olfactory nerves
Internal nasal branch of anterior ethmoidal nerve
Anterior superior alveolar nerve
Nasopalatine nerve from pterygopalatine ganglion

Fig. 15.7: Nerve supply of the nasal septum

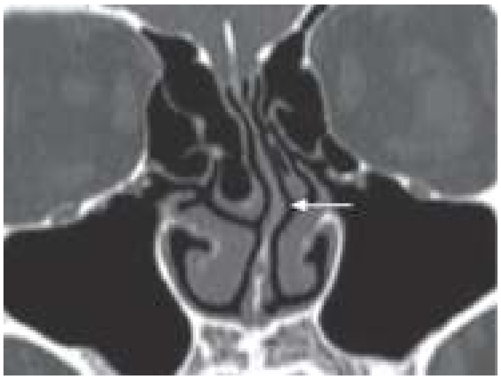


Fig. 15.8: Deviated nasal septum

DISSECTION

Take the sagittal section of head and neck. Dissect and remove mucous membrane of the septum of nose in small pieces. The mucous membrane is covering both surfaces of the septum of the nose.

Dissect and preserve the nerves lying in the mucous membrane. Remove the entire mucous membrane to see the details in the interior of the nasal cavity.

LATERAL WALL OF NOSE

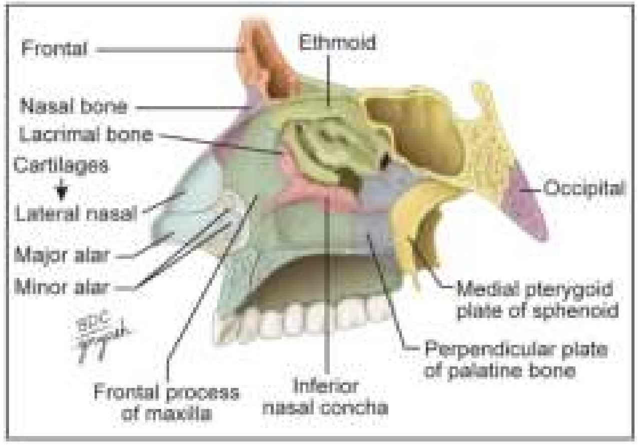
The lateral wall of the nose is irregular owing to the presence of three shelf-like bony projections called *conchae.* The conchae increase the surface area of the nose for effective air-conditioning of the inspired air (Plate 15.2).

Parts

The lateral wall can be subdivided into three parts:

a. A small depressed area in the anterior part is called the ***vestibule***. It is lined by modified skin containing short, stiff, curved hairs called ***vibrissae***.
b. The middle part is known as the ***atrium*** of the middle meatus.
c. The posterior part contains the ***conchae***. Spaces separating the conchae are called meatuses (Fig. 15.9).

Plate 15.2: Bony formation of the lateral wall of the nasal cavity


Frontal
Ethmoid
Nasal bone
Lacrimal bone
Cartilages
Lateral nasal
Major alar
Minor alar
Occipital
Medial pterygoid plate of sphenoid
Perpendicular plate of palatine bone
Frontal process of maxilla
Inferior nasal concha

Formation

The *skeleton of the lateral wall* is partly bony, partly cartilaginous, and partly made up only of soft tissues (Plate 15.3, Fig. 15.9).

1. ***Bony part*** is formed from before backwards by the following bones:
   a. Nasal
   b. Frontal process of maxilla
   c. Lacrimal
   d. Labyrinth of ethmoid with superior and middle conchae
   e. Inferior nasal concha, made up of spongy bone only
   f. Perpendicular plate of palatine bone together with its orbital and sphenoidal processes
   g. Medial pterygoid plate.
2. ***Cartilaginous part*** is formed by:
   a. Superior nasal cartilage
   b. Inferior nasal cartilage
   c. 3 or 4 small cartilages of the ala.
3. ***Cuticular lower part*** is formed by fibrofatty tissue covered with skin.

Features of Conchae and Meatuses

Nasal Conchae

These are curved bony projections directed downwards and medially. The following three conchae are usually found:

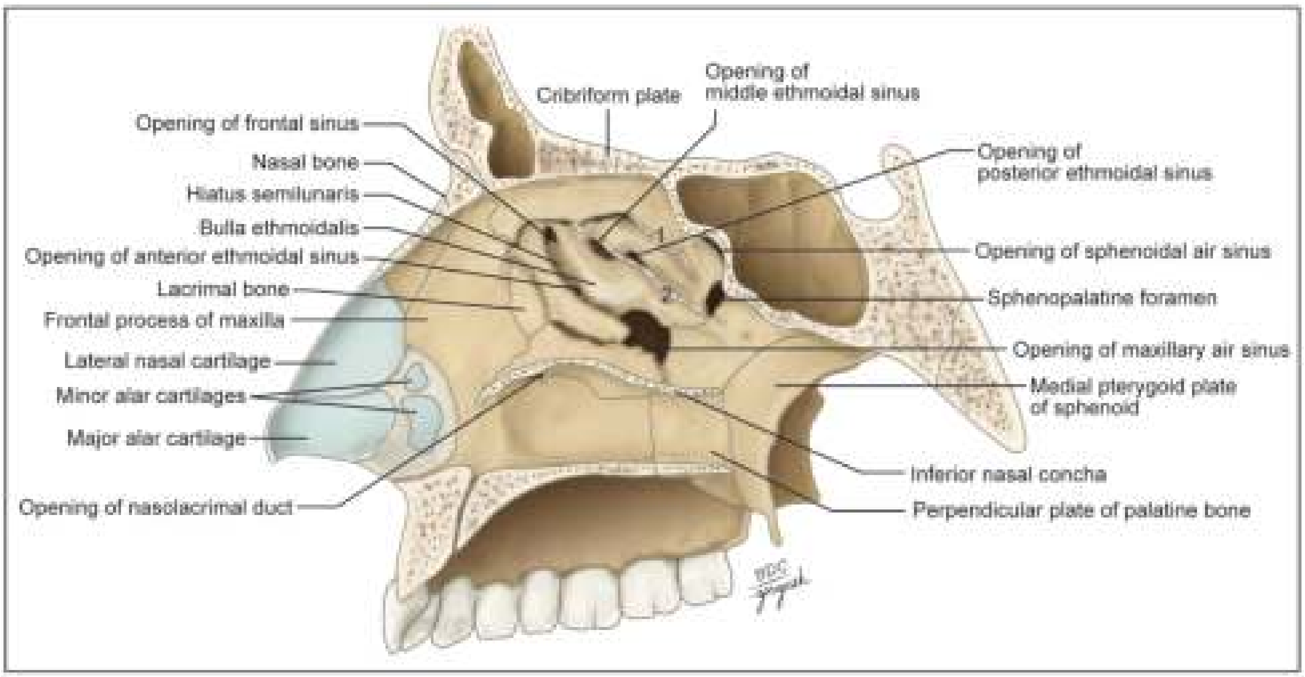
1. ***Inferior concha*** (Latin *shell*) is an independent bone.
2. ***Middle concha*** is a projection from the medial surface of ethmoidal labyrinth.
3. ***Superior concha*** is also a projection from the medial surface of the ethmoidal labyrinth. This is the smallest concha situated just above the posterior part of the middle concha.

Meatuses of the Nose

These are passages beneath the overhanging conchae. Each meatus communicates freely with the nasal cavity proper (Fig. 15.9 and Flowchart 15.2).

1. ***Inferior meatus*** lies underneath the inferior concha, and is the largest of the three meatuses. The nasolacrimal

Plate 15.3: Formation of the lateral wall of the nasal cavity (bony formation and openings, 1: Superior concha and 2: inferior concha of ethmoid bone)


Opening of frontal sinus
Nasal bone
Hiatus semilunaris
Bulla ethmoidalis
Opening of anterior ethmoidal sinus
Lacrimal bone
Frontal process of maxilla
Lateral nasal cartilage
Minor alar cartilages
Major alar cartilage
Opening of nasolacrimal duct
Cribriform plate
Opening of middle ethmoidal sinus
Opening of posterior ethmoidal sinus
Opening of sphenoidal air sinus
Sphenopalatine foramen
Opening of maxillary air sinus
Medial pterygoid plate of sphenoid
Inferior nasal concha
Perpendicular plate of palatine bone
1
2

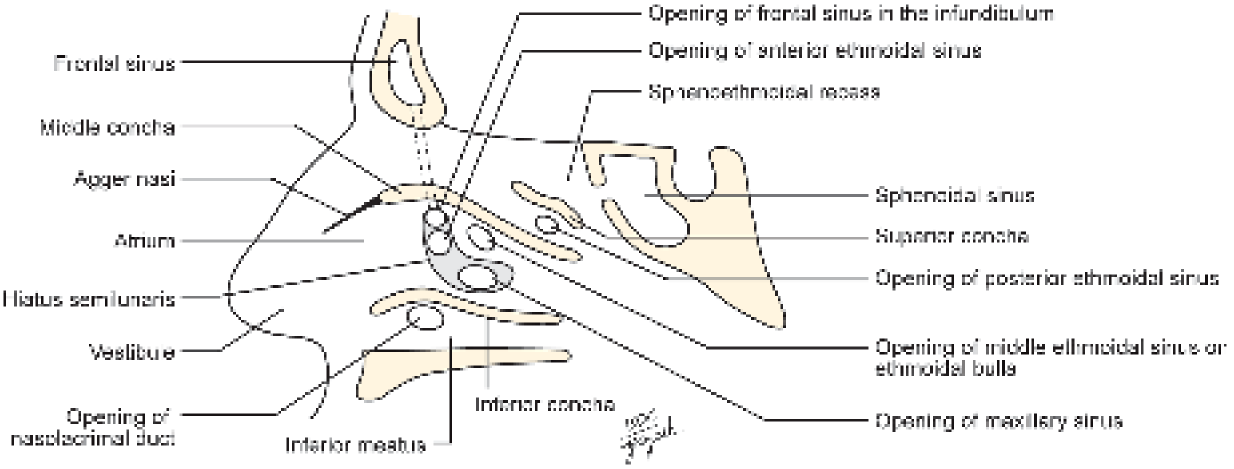
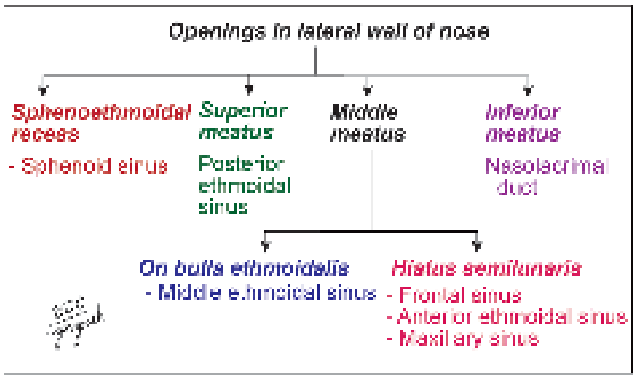

Frontal sinus
Middle concha
Agger nasi
Atrium
Hiatus semilunaris
Vestibule
Opening of nasolacrimal duct
Inferior meatus
Inferior concha
Opening of frontal sinus in the infundibulum
Opening of anterior ethmoidal sinus
Sphenoethmoidal recess
Sphenoidal sinus
Superior concha
Opening of posterior ethmoidal sinus
Opening of middle ethmoidal sinus on ethmoidal bulla
Opening of maxillary sinus

Fig. 15.9: Lateral wall of the nasal cavity seen after removing the conchae

Flowchart 15.2: Openings in lateral wall of nose


Openings in lateral wall of nose
Sphenoethmoidal recess
- Sphenoid sinus
Superior meatus
Posterior ethmoidal sinus
Middle meatus
Inferior meatus
Nasolacrimal duct
On bulla ethmoidalis
- Middle ethmoidal sinus
Hiatus semilunaris
- Frontal sinus
- Anterior ethmoidal sinus
- Maxillary sinus

duct opens into it at the junction of its anterior one-third and posterior two-thirds. The opening is guarded by the lacrimal fold, or ***Hasner's valve***.

2. ***Middle meatus*** lies underneath the middle concha. It presents the following features:
   a. *Ethmoidal bulla* is a rounded elevation produced by the underlying middle ethmoidal sinuses which open at upper margin of bulla.
   b. *Hiatus semilunaris* is a deep semicircular sulcus below the bulla.
   c. *Infundibulum* is a short passage at the anterior end of the hiatus.
   d. *Openings*:

      Opening of *frontal air sinus* is seen in the anterior part of hiatus semilunaris.

      Opening of *the anterior ethmoidal air sinus* is present behind the opening of frontal air sinus.

      Opening of *maxillary air sinus* is located in posterior part of the hiatus semilunaris. It is often represented by two openings.

3. ***Superior meatus*** lies below the superior concha. This is the shortest and shallowest of the three meatuses. It receives the *openings of the posterior ethmoidal air sinuses.*
4. ***Sphenoethmoidal recess*** is a triangular fossa just above the superior concha. It receives the *opening of the sphenoidal air sinus.*

Note: The ***atrium of the middle meatus*** is a shallow depression just in front of the middle meatus and above the vestibule of the nose. It is limited above by a faint ridge of mucous membrane, the ***agger nasi***, which runs forwards and downwards from the upper end of the anterior border of the middle concha (Fig. 15.8).

Arterial Supply (Fig. 15.10)

1. *Anterosuperior quadrant* is supplied by the anterior ethmoidal artery assisted by the posterior ethmoidal artery.
2. *Anteroinferior quadrant* is supplied by branches from the facial artery.
3. *Posterosuperior quadrant* is supplied by a few branches of the sphenopalatine artery.
4. *Posteroinferior quadrant* is supplied by branches from greater palatine artery which pierce the perpendicular plate of palatine bone to run on the hard palate and passes up in the nose through the incisive fossa.

Venous Drainage

The veins form a plexus which drains anteriorly into the facial vein; posteriorly, into the pharyngeal plexus of veins; and from the middle part, to the pterygoid plexus of veins.

Nerve Supply

General sensory nerves: They derived from the branches of trigeminal nerve are distributed to whole of the lateral wall (Fig. 15.11):

1. *Anterosuperior quadrant* is supplied by the anterior ethmoidal nerve branch of ophthalmic nerve.
2. *Anteroinferior quadrant* is supplied by the anterior superior alveolar nerve, branch of infraorbital, continuation of maxillary nerve.
3. *Posterosuperior quadrant* is supplied by the lateral posterior superior nasal branches from the pterygopalatine ganglion.
4. *Posteroinferior quadrant* is supplied by the anterior palatine branch from the pterygopalatine ganglion.

Special sensory nerves or olfactory nerves: They are distributed to the upper part of the lateral wall just below the cribriform plate of the ethmoid up to the superior concha.

Note that the olfactory mucosa lies partly on the lateral wall and partly on the nasal septum.

Lymphatic Drainage

Lymphatics from the anterior half of the lateral wall pass to the submandibular nodes, and from the posterior half, to the retropharyngeal and upper deep cervical nodes.

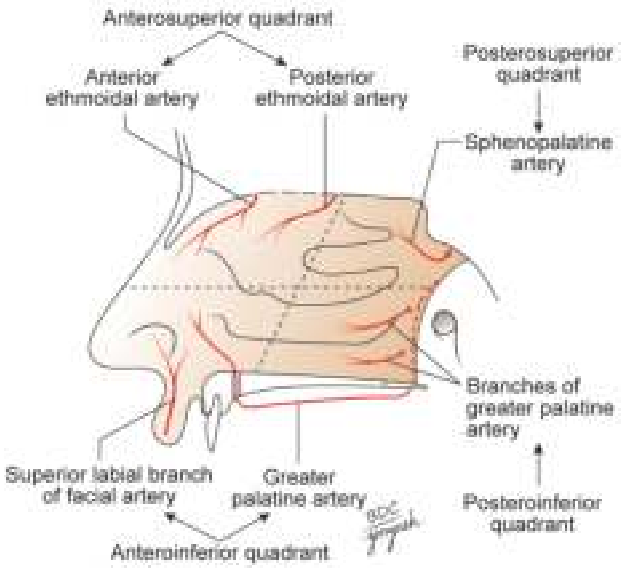

Anterosuperior quadrant
Anterior ethmoidal artery
Posterior ethmoidal artery
Posterosuperior quadrant
Sphenopalatine artery
Branches of greater palatine artery
Posteroinferior quadrant
Superior labial branch of facial artery
Greater palatine artery
Anteroinferior quadrant

Fig. 15.10: Arteries supplying lateral wall of the nasal cavity

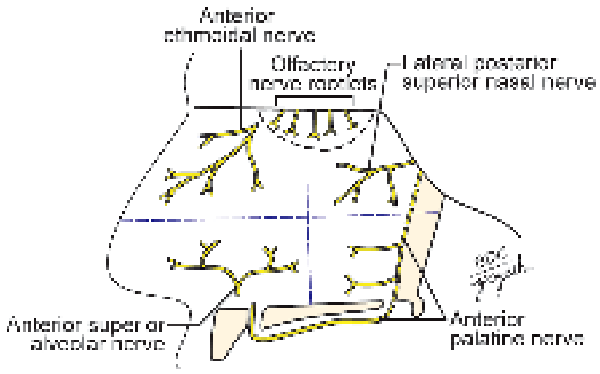

Anterior ethmoidal nerve
Olfactory nerve rootlets
Lateral posterior superior nasal nerve
Anterior superior alveolar nerve
Anterior palatine nerve

Fig. 15.11: Nerve supply of lateral wall of the nasal cavity

CLINICAL ANATOMY

Hypertrophy of the mucosa over the inferior nasal concha is a common feature of allergic rhinitis, which is characterised by sneezing, nasal blockage and excessive watery discharge from the nose.

DISSECTION

Remove with scissors the anterior part of inferior nasal concha. This will reveal the opening of the nasolacrimal duct. Pass a thin probe upwards through the nasolacrimal duct into the lacrimal sac at the medial angle of the eye. Remove all the three nasal conchae to expose the meatuses lying below the respective concha. This will expose the openings of the sinuses present there.

Trace the nasopalatine nerve till the sphenopalatine foramen. Try to find a few nasal branches of the greater palatine nerve.

Gently break the perpendicular plate of palatine bone to expose the greater or anterior palatine nerve, branch of the pterygopalatine ganglion. Follow the nerve and its accompanying vessels to the hard palate. Identify the lesser or middle palatine nerves and trace them till the soft palate.

OLFACTORY NERVE—1ST NERVE

1. The *olfactory cells* (16–20 million in man) are bipolar neurons. They lie in the olfactory part of the nasal mucosa and serve both as receptors as well as the first neurons in the olfactory pathway (Fig. 15.12).
2. The *olfactory nerves*, about 20 in number, represent central processes of the olfactory cells. They pass through the cribriform plate of ethmoid and make synaptic glomeruli with cells of olfactory bulb.
3. The mitral and tufted cells in the olfactory bulb give off fibres that form the *olfactory tract* and reach the anterior perforated substance and uncus.

CLINICAL ANATOMY

- Anosmia: Loss of olfactory fibres with ageing.
- Sense of smell is tested separately in each nostril.
- Allergic rhinitis causes temporary olfactory impairment.

Competency:

AN37.2 Describe location and functional anatomy of paranasal sinuses.

PARANASAL SINUSES

Paranasal sinuses are air-filled spaces present within some bones around the nasal cavities. The sinuses are *frontal, maxillary, sphenoidal and ethmoidal.* All of them open into the nasal cavity through its lateral wall (Fig. 15.12 and Flowchart 15.3).

Functions

The *function* of the sinuses is to make the skull lighter, warm up and humidify the inspired air. These also add resonance to the voice. In infections of the sinuses or *sinusitis,* the voice is altered.

Note: The sinuses are rudimentary, or even absent at birth. They enlarge rapidly during the ages of 6 to 7 years, i.e. time of eruption of permanent teeth and then after puberty. From birth to adult life, the growth of the sinuses is due to enlargement of the bones; in old age, it is due to resorption of the surrounding cancellous bone.

Frontal Sinus

1. The frontal sinus lies in the frontal bone deep to the superciliary arch. It extends upwards above the medial end of the eyebrow, and backwards into the medial part of the roof of the orbit.
2. It *opens* into the middle meatus of nose at the anterior end of the hiatus semilunaris either through the infundibulum or through the frontonasal duct.
3. The right and left sinuses are usually unequal in size; and rarely one or both may be absent. Their *average* height, width and anteroposterior depth are each about 2.5 cm. The sinuses are better developed in males than in females.
4. They are rudimentary or absent at birth. They are well developed between 7 and 8 years of age, but reach full size only after puberty.

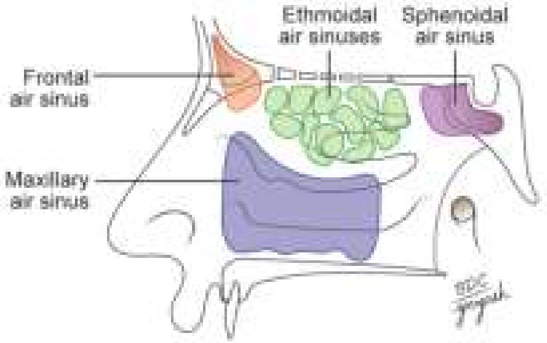
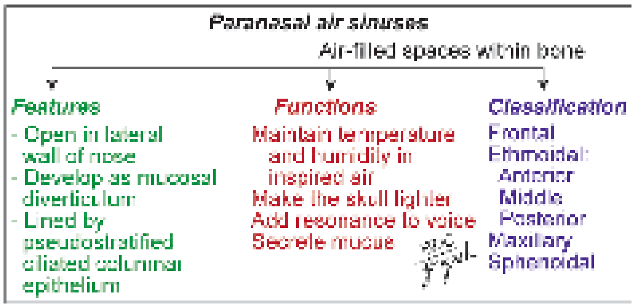

Ethmoidal air sinuses
Sphenoidal air sinus
Frontal air sinus
Maxillary air sinus

Fig. 15.12: Lateral wall of nasal cavity with location of paranasal sinuses

Flowchart 15.3: Paranasal air sinuses


Paranasal air sinuses
Air-filled spaces within bone
Features
- Open in lateral wall of nose
- Develop as mucosal diverticulum
- Lined by pseudostratified ciliated columnar epithelium
Functions
Maintain temperature and humidity in inspired air
Make the skull lighter
Add resonance to voice
Secrete mucus
Classification
Frontal
Ethmoidal:
Anterior
Middle
Posterior
Maxillary
Sphenoidal

Arterial supply: Supraorbital artery.

Venous drainage: Into the supraorbital and superior ophthalmic veins.

Lymphatic drainage: To submandibular nodes.

Nerve supply: Supraorbital nerve.

Maxillary Sinus (Fig. 15.13 and Flowchart 15.4)

1. The maxillary sinus lies in the body of the maxilla, and is the largest of all the paranasal sinuses. It is pyramidal in shape, with its base directed medially towards the lateral wall of the nose, and the apex directed laterally in the zygomatic process of the maxilla.
2. It *opens* into the middle meatus of the nose in the lower part of the hiatus semilunaris. *The opening/hiatus is nearer the roof.*
3. In an isolated maxilla, the opening or hiatus of the maxillary sinus is large. However, in the intact skull, the size of opening is reduced to 3 or 4 mm as it is overlapped by the following:
   a. From above, by the uncinate process of the ethmoid, and the descending part of lacrimal bone.
   b. From below, by lacrimal and ethmoidal processes of inferior nasal concha.
   c. From behind, by perpendicular plate of palatine bone and by the ethmoidal process of inferior nasal concha. It is further reduced in size by the thick mucosa of nose.
4. The size of sinus is variable. Average measurements are: Height—3.5 cm, width—2.5 cm and anteroposterior depth—3.5 cm.

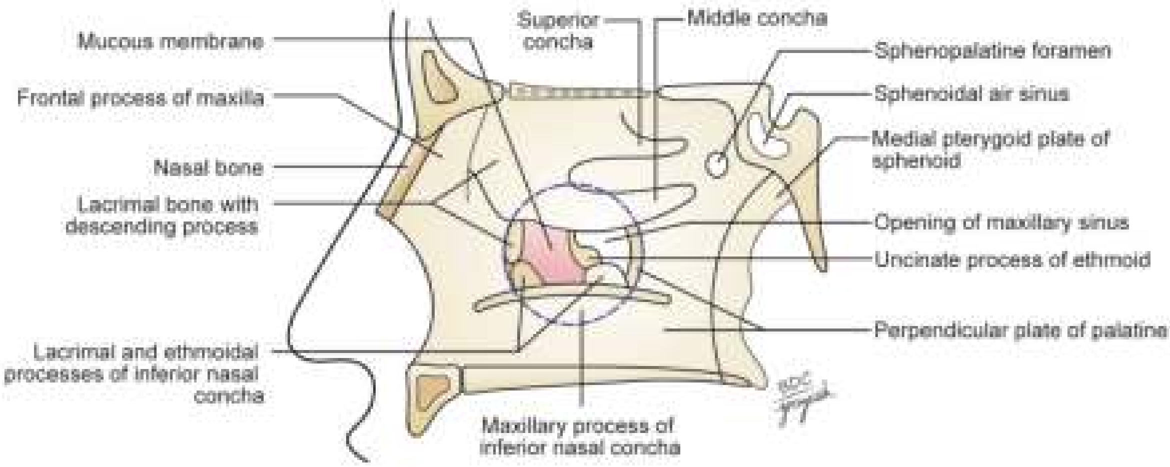
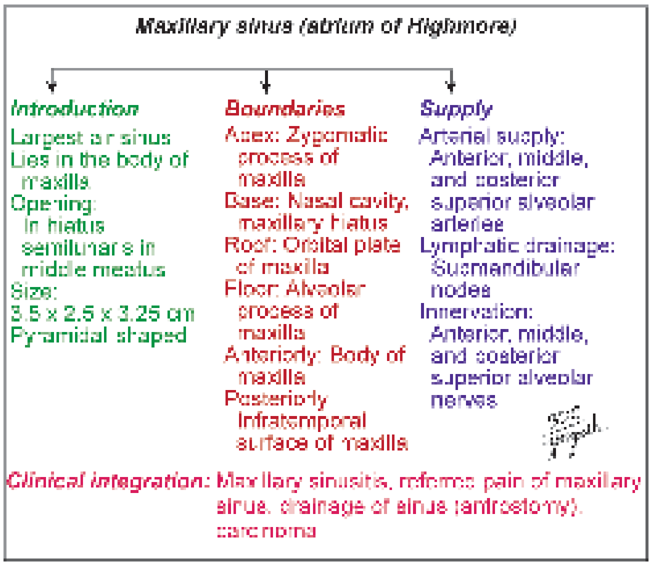

Mucous membrane
Frontal process of maxilla
Nasal bone
Lacrimal bone with descending process
Lacrimal and ethmoidal processes of inferior nasal concha
Superior concha
Middle concha
Sphenopalatine foramen
Sphenoidal air sinus
Medial pterygoid plate of sphenoid
Opening of maxillary sinus
Uncinate process of ethmoid
Perpendicular plate of palatine
Maxillary process of inferior nasal concha

Fig. 15.13: Reduced size of maxillary air sinus

Flowchart 15.4: Maxillary sinuses


Maxillary sinus (atrium of Highmore)
Introduction
Largest air sinus
Lies in the body of maxilla
Opening:
In hiatus semilunaris in middle meatus
Size:
3.5 x 2.5 x 3.25 cm
Pyramidal shaped
Boundaries
Apex: Zygomatic process of maxilla
Base: Nasal cavity, maxillary hiatus
Roof: Orbital plate of maxilla
Floor: Alveolar process of maxilla
Anteriorly: Body of maxilla
Posteriorly Infratemporal surface of maxilla
Supply
Arterial supply:
Anterior, middle, and posterior superior alveolar arteries
Lymphatic drainage:
Submandibular nodes
Innervation:
Anterior, middle, and posterior superior alveolar nerves
Clinical integration: Maxillary sinusitis, referred pain of maxillary sinus, drainage of sinus (antrostomy), carcinoma

5. Its *roof* is formed by the floor of orbit, and is traversed by the infraorbital nerve. The *floor* is formed by the alveolar process of maxilla, and lies about 1 cm below the level of floor of the nose. The level corresponds to the level of lower border of the ala of nose. The floor is marked by several conical elevations produced by the roots of upper molar and premolar teeth. The roots may even penetrate the bony floor to lie beneath the mucous lining. The canine tooth may project into the anterolateral wall.
6. The maxillary sinus is the first paranasal sinus to *develop*.

Arterial supply: Facial, infraorbital and greater palatine arteries.

Venous drainage into the facial vein and the pterygoid plexus of veins.

Lymphatic drainage into the submandibular nodes.

Nerve supply: Posterior superior alveolar branches from maxillary nerve and anterior and middle superior alveolar branches from infraorbital nerve.

Sphenoidal Sinus

1. The right and left sphenoidal sinuses lie within the body of sphenoid bone. They are separated by a septum. The two sinuses are usually unequal in size. Each sinus opens into the sphenoethmoidal recess of corresponding half of the nasal cavity.
2. Each sinus is related superiorly to the optic chiasma and the hypophysis cerebri; and laterally to the internal carotid artery and the cavernous sinus.

Arterial supply: Posterior ethmoidal and internal carotid arteries.

Venous drainage: Into pterygoid venous plexus and cavernous sinus.

Lymphatic drainage: To the retropharyngeal nodes.

Nerve supply: Posterior ethmoidal nerve and orbital branches of pterygopalatine ganglion.

Ethmoidal Sinuses

Ethmoidal sinuses are numerous small intercommunicating spaces which lie within the labyrinth of the ethmoid bone. They are completed from above by the orbital plate of the frontal bone, from behind by the sphenoidal conchae and the orbital process of the palatine bone, and anteriorly by the lacrimal bone. The sinuses are divided into anterior, middle and posterior groups.

A. ***Anterior ethmoidal sinus*** is made up of 1 to 11 air cells, opens into the anterior part of the hiatus semilunaris of the nose. It is supplied by the anterior ethmoidal nerve and vessels. Its lymphatics drain into the submandibular nodes.
B. ***Middle ethmoidal sinus*** consisting of 1 to 7 air cells open into the middle meatus of the nose. It is supplied by the anterior ethmoidal nerve and vessels and the orbital branches of the pterygopalatine ganglion. Lymphatics drain into the submandibular nodes.
C. ***Posterior ethmoidal sinus*** consisting of 1 to 7 air cells open into the superior meatus of the nose. It is supplied by the posterior ethmoidal

nerve and vessels and the orbital branches of the pterygopalatine ganglion. Lymphatics drain into the retropharyngeal nodes.

Competency:
AN37.3 Describe anatomical basis of sinusitis and maxillary sinus tumours.

CLINICAL ANATOMY

- Infection of a sinus is known as ***sinusitis***. It causes headache and persistent, thick, purulent discharge from the nose. Diagnosis is assisted by transillumination and radiography. A diseased sinus is opaque.
- Openings of anterior ethmoidal, frontal and maxillary sinuses in middle meatus is known as ***ostiomeatal complex***.
- ***Anterior ethmoiditis*** narrows the ostiomeatal complex preventing proper drainage from the sinuses. Hence, anterior ethmoiditis is also common cause of chronic sinusitis.
- ***Frontal sinusitis*** and ***ethmoiditis*** can cause oedema of the lids secondary to infection of the sinuses.
- Pain from ethmoid air sinus may be referred to forehead, as both are supplied by ophthalmic division of trigeminal nerve.
- Opening of maxillary air sinus is near the roof of sinus. It cannot drain properly. So ***maxillary sinusitis*** is the commonest cause of chronic sinusitis.
- The maxillary sinus may be infected from the nose or from a caries tooth. Drainage of the sinus is difficult because its ostium lies at a higher level than its floor. Hence, the sinus is drained surgically by:
  - ***Antrum puncture*** can be done by breaking the lateral wall of the inferior meatus and pushing in fluid and letting it drain through the natural orifice with head in dependent position (Fig. 15.14).
- ***Carcinoma of the maxillary sinus*** arises from the mucosal lining.
- Pain of maxillary sinusitis may be referred to upper teeth and infraorbital skin as all these are supplied by the maxillary nerve.

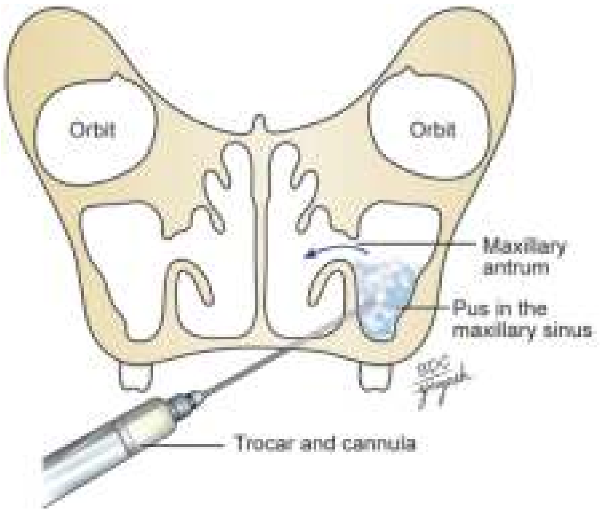


Fig. 15.14: Antrum puncture

DISSECTION

Remove the thin medial walls of the ethmoidal air cells, and look for the continuity with the mucous membrane of the nose. Remove the medial wall of maxillary air sinus extending anteriorly from opening of nasolacrimal duct till the greater palatine canal posteriorly. Now maxillary air sinus can be seen. Remove part of the roof of maxillary air sinus so that the maxillary nerve and pterygopalatine ganglion are identifiable in the pterygopalatine fossa.

Trace the infraorbital nerve in infraorbital canal in floor of orbit. Try to locate the sinuous course of anterior superior alveolar nerve into the upper incisor teeth.

PTERYGOPALATINE FOSSA

This is small pyramidal space situated deeply, below the apex of the orbit (Fig. 15.15 and Flowchart 15.5).

Boundaries

Anterior:	Superomedial part of the posterior surface of the maxilla.
Posterior:	Root of the pterygoid process and adjoining part of the anterior surface of the greater wing of the sphenoid.
Medial:	Upper part of the perpendicular plate of the palatine bone. The orbital and sphenoidal processes of the bone also take part.
Lateral:	The fossa opens into the infratemporal fossa through the pterygomaxillary fissure
Superior:	Undersurface of the body of sphenoid.
Inferior:	Closed by the pyramidal process of the palatine bone in the angle between the maxilla and the pterygoid process.

Communications

Anteriorly: With the orbit through the medial end of the inferior orbital fissure.

Posteriorly:

1. Middle cranial fossa through the foramen rotundum.
2. Foramen lacerum through the pterygoid canal.
3. Pharynx through the palatinovaginal canal.

Medially: With the nose through sphenopalatine foramen.

Laterally: With the infratemporal fossa through the pterygomaxillary fissure.

Inferiorly: With the oral cavity through the greater and lesser palatine canals.

Contents

1. Third part of the maxillary artery and its branches which bear the same names as the branches of the pterygopalatine ganglia and accompany all of them.
2. Maxillary nerve and its branches—ganglionic, zygomatic and posterior superior alveolar.
3. Pterygopalatine ganglion with its roots and its numerous branches containing fibres of the maxillary nerve mixed with autonomic nerves (described below).

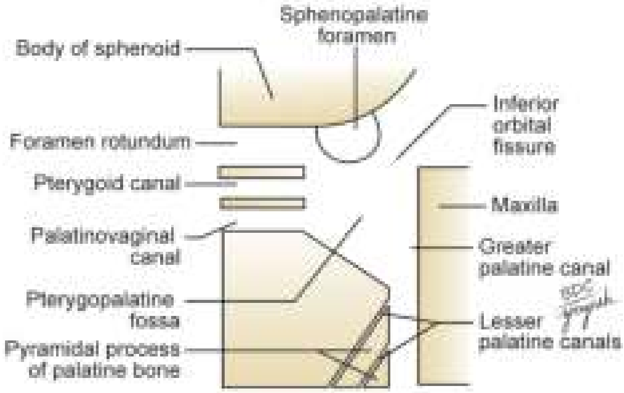
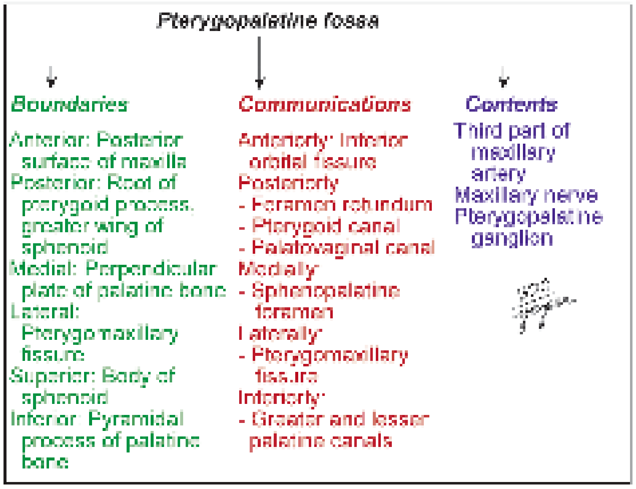

Sphenopalatine foramen
Body of sphenoid
Inferior orbital fissure
Foramen rotundum
Pterygoid canal
Maxilla
Palatinovaginal canal
Greater palatine canal
Pterygopalatine fossa
Lesser palatine canals
Pyramidal process of palatine bone

Fig. 15.15: Scheme to show the pterygopalatine fossa and its communications

Flowchart 15.5: Pterygopalatine fossa



Pterygopalatine fossa

Boundaries
Anterior: Posterior surface of maxilla
Posterior: Root of pterygoid process, greater wing of sphenoid
Medial: Perpendicular plate of palatine bone
Lateral: Pterygomaxillary fissure
Superior: Body of sphenoid
Inferior: Pyramidal process of palatine bone

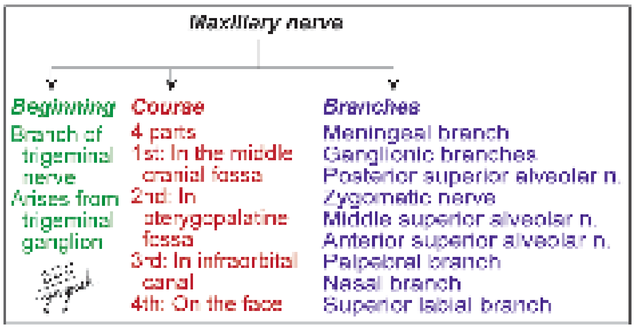
Communications
Anteriorly: Inferior orbital fissure
Posteriorly
- Foramen rotundum
- Pterygoid canal
- Palatovaginal canal
Medially
- Sphenopalatine foramen
Laterally
- Pterygomaxillary fissure
Inferiorly
- Greater and lesser palatine canals

Contents
Third part of maxillary artery
Maxillary nerve
Pterygopalatine ganglion

Maxillary Nerve

It arises from the trigeminal ganglion, runs forwards, and leaves the middle cranial fossa by passing through the foramen rotundum. Next, the nerve crosses the upper part of pterygopalatine fossa, beyond which it is continued as the infraorbital nerve (Fig. 15.16 and Flowchart 15.6).

Flowchart 15.6: Maxillary nerve



Maxillary nerve

Beginning
Branch of trigeminal nerve
Arises from trigeminal ganglion

Course
4 parts
1st: In the middle cranial fossa
2nd: In pterygopalatine fossa
3rd: In infraorbital canal
4th: On the face

Branches
Meningeal branch
Ganglionic branches
Posterior superior alveolar n.
Zygomatic nerve
Middle superior alveolar n.
Anterior superior alveolar n.
Palpebral branch
Nasal branch
Superior labial branch

In the middle cranial fossa, maxillary nerve gives a meningeal branch.

In the pterygopalatine fossa, the nerve is related to the pterygopalatine ganglion, and gives off the ganglionic, posterior superior alveolar and zygomatic nerves.

Ganglionic Branches

The pterygopalatine ganglion is suspended by the ganglionic branches.

Posterior Superior Alveolar Nerve

It enters the posterior surface of the body of the maxilla, and supplies the three upper molar teeth and the adjoining part of the gum.

Zygomatic Nerve

It is a branch of the maxillary nerve, given off in the pterygopalatine fossa. It enters the orbit through the lateral end of the inferior orbital fissure, and runs along the lateral wall, outside the periosteum, to enter the zygomatic bone. Just before or after entering the bone, it divides into two terminal branches, the *zygomaticofacial* and *zygomaticotemporal nerves* which supply the skin of the face and of the anterior part of the temple. The communicating branch to the lacrimal nerve, which contains secretomotor fibres to the lacrimal gland, arises from the zygomaticotemporal nerve, and runs in the lateral wall of the orbit.

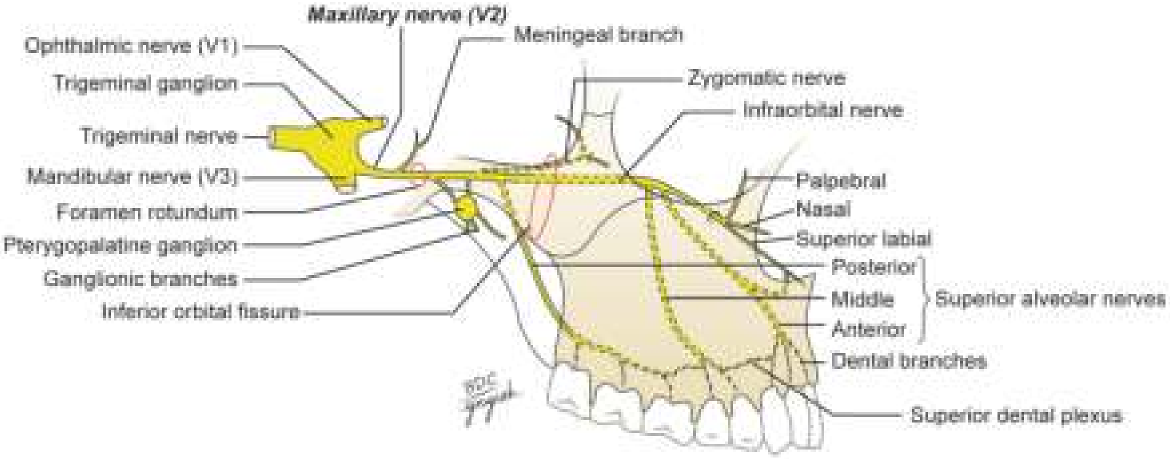

Maxillary nerve (V2)
Meningeal branch
Ophthalmic nerve (V1)
Trigeminal ganglion
Zygomatic nerve
Infraorbital nerve
Trigeminal nerve
Mandibular nerve (V3)
Palpebral
Nasal
Foramen rotundum
Superior labial
Pterygopalatine ganglion
Posterior
Middle
Anterior
Superior alveolar nerves
Ganglionic branches
Inferior orbital fissure
Dental branches
Superior dental plexus

Fig. 15.16: Branches of maxillary nerve

Infraorbital Nerve

It is the continuation of the maxillary nerve. It enters the orbit through the *inferior orbital fissure*. It then runs forwards on the floor of the orbit or the roof of the maxillary sinus, at first in the *infraorbital groove* and then in the *infraorbital canal* remaining outside the periosteum of the orbit. It emerges on the face through the *infraorbital foramen* and terminates by dividing into palpebral, nasal and labial branches. The nerve is accompanied by the infraorbital branch of the third part of the maxillary artery and the accompanying vein.

Branches

1. *Middle superior alveolar nerve* arises in the infraorbital groove, runs in the lateral wall of the maxillary sinus, and supplies the upper premolar teeth.
2. *Anterior superior alveolar nerve* arises in the infraorbital canal, and runs in a sinuous canal having a complicated course in the anterior wall of the maxillary sinus. It supplies the upper incisor and canine teeth, the maxillary sinus, and the anteroinferior part of the nasal cavity.
3. *Terminal branches—palpebral, nasal and labial* supply a large area of skin on the face. They also supply the mucous membrane of the upper lip and cheek.

PTERYGOPALATINE GANGLION

Synonyms: Sphenopalatine ganglion, ganglion of Hay fever, or Meckel's ganglion (Figs 15.17a and b, Flowchart 15.7).

Features

The pterygopalatine is the largest parasympathetic peripheral ganglion. It is a relay station for secretomotor fibres to the lacrimal gland and to the mucous glands of the nose, paranasal sinuses, palate and pharynx.

Neurological Relationship

- *Topographic relation*: It is related to the maxillary nerve.
- *Functional relation*: Functionally, it is connected to the facial nerve through its greater petrosal branch.

Location

The flattened ganglion lies on the pterygopalatine fossa just below the maxillary nerve, in front of the pterygoid canal and lateral to the sphenopalatine foramen.

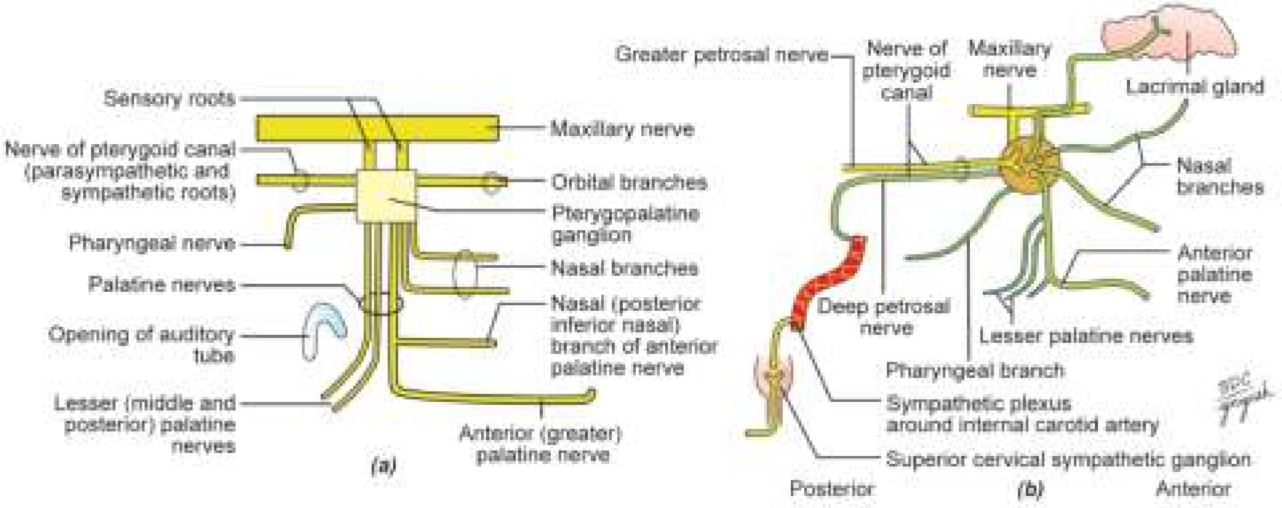
Connections

It has three roots as follows:

1. ***Parasympathetic* or *secretomotor root*:** It consists of pre- and post-ganglionic fibres:

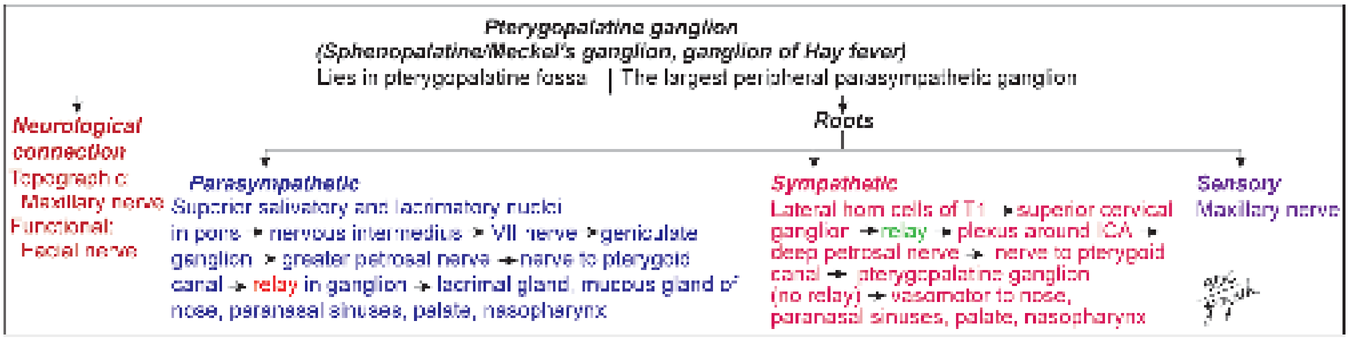
   Preganglionic fibres arise from *superior salivatory* and *lacrimatory nuclei* in pons and pass through the *nervous intermedius*, the *facial nerve*, the *geniculate ganglion*, the *greater petrosal nerve*, and the *nerve of the pterygoid canal* to reach and relay in the *ganglion*.

   Postganglionic fibres arise in the ganglion to supply secretomotor nerves to the lacrimal gland and the


Sensory roots
Nerve of pterygoid canal (parasympathetic and sympathetic roots)
Pharyngeal nerve
Palatine nerves
Opening of auditory tube
Lesser (middle and posterior) palatine nerves
Maxillary nerve
Orbital branches
Pterygopalatine ganglion
Nasal branches
Nasal (posterior inferior nasal) branch of anterior palatine nerve
Anterior (greater) palatine nerve
(a)
Greater petrosal nerve
Nerve of pterygoid canal
Maxillary nerve
Lacrimal gland
Nasal branches
Anterior palatine nerve
Deep petrosal nerve
Lesser palatine nerves
Pharyngeal branch
Sympathetic plexus around internal carotid artery
Superior cervical sympathetic ganglion
Posterior
(b)
Anterior

Figs 15.17a and b: Pterygopalatine ganglion: (a) Connections and branches and (b) roots and branches

Flowchart 15.7: Pterygopalatine ganglion


Pterygopalatine ganglion
(Sphenopalatine/Meckel's ganglion, ganglion of Hay fever)
Lies in pterygopalatine fossa
The largest peripheral parasympathetic ganglion
Neurological connection
Topographic: Maxillary nerve
Functional: Facial nerve
Roots
Parasympathetic
Superior salivatory and lacrimatory nuclei in pons → nervous intermedius → VII nerve → geniculate ganglion → greater petrosal nerve → nerve to pterygoid canal → relay in ganglion → lacrimal gland, mucous gland of nose, paranasal sinuses, palate, nasopharynx
Sympathetic
Lateral horn cells of T1 → superior cervical ganglion → relay → plexus around ICA → deep petrosal nerve → nerve to pterygoid canal → pterygopalatine ganglion (no relay) → vasomotor to nose, paranasal sinuses, palate, nasopharynx
Sensory
Maxillary nerve

mucous glands of the nose, the paranasal sinuses, the palate, and the nasopharynx.

2. ***Sympathetic root*:** The lateral horn cells of T1 segment of spinal cord give rise to the preganglionic sympathetic fibres. They traverse to T1 nerve, sympathetic chain, and relay in superior cervical sympathetic ganglion. Postganglionic fibres pass through internal carotid plexus, the *deep petrosal nerve*, and the *nerve of the pterygoid canal* to reach the ganglion. The fibres pass through the ganglion without relay, supply vasomotor nerves to the mucous membrane of the nose, the paranasal sinuses, the palate, and the nasopharynx.
3. ***Sensory roots*:** These are the fibres of maxillary nerve. Its fibres pass through the ganglion without relay. They emerge in the branches.

Branches

1. *Orbital branches* pass through the inferior orbital fissure, and supply the periosteum of the orbit, and the orbitalis muscle which is involuntary (Table 15.1).
2. *Palatine branches*: *Greater or anterior palatine nerve* descends through the greater palatine canal, and supplies the hard palate and the labial aspect of the upper gums. The *lesser or posterior palatine nerves* supply the soft palate and the tonsil.
3. *Nasal branches* enter the nasal cavity through the sphenopalatine foramen.
   a. *Lateral posterior superior nasal branches* (six in number) supply the posterior parts of the superior and middle conchae.
   b. *Medial posterior superior nasal branches*, two or three in number, supply the posterior part of the roof of the nose and of the nasal septum. The largest of these nerves is known as the *nasopalatine nerve* which descends up to the anterior part of the hard palate through the incisive foramen.
4. *Pharyngeal branch* passes through the palatinovaginal canal and supplies the part of the nasopharynx behind the auditory tube.
5. *Lacrimal branch*: The postganglionic fibres pass back into the maxillary nerve to leave it through its zygomatic nerve and its zygomaticotemporal branch, a communicating branch to lacrimal nerve to supply the secretomotor fibres to the lacrimal gland.

TABLE 15.1: Branches of pterygopalatine ganglion

Branch	*Functions*
Orbital branches	Periosteum of the orbit, orbitalis muscle
Palatine branches	
a. Greater or anterior palatine nerve	Hard palate, labial aspect of the upper gums
b. Lesser or posterior palatine nerve	Soft palate and the tonsil
Nasal branches	
a. Lateral posterior superior nasal branches (6)	Posterior parts of the superior and middle conchae
b. Medial posterior superior nasal branches (2–3)	Posterior part of the roof of the nose and of the nasal septum Nasopalatine nerve (largest branch) – anterior part of the hard palate
Pharyngeal branch	Part of the nasopharynx behind the auditory tube
Lacrimal branch	Parasympathetic supply of lacrimal gland

DISSECTION

Trace the connections, and branches of pterygopalatine ganglion. It is responsible for supplying secretomotor fibres to the glands of nasal cavity, palate, pharynx, and the lacrimal gland. It is also called *hay fever ganglion* as inflammation of the ganglion causes allergic sinusitis.

CLINICAL ANATOMY

- The pterygopalatine ganglion, if irritated or infected, causes congestion of the glands of palate and nose including the lacrimal gland producing running nose and lacrimation. The condition is called hay fever. The ganglion is called '***ganglion of hay fever***.
- Maxillary nerve carries the afferent limb fibres of the sneeze reflex as it carries general sensation from the nasal mucous membrane.

VIDEO

Video 3.15 **Nose**

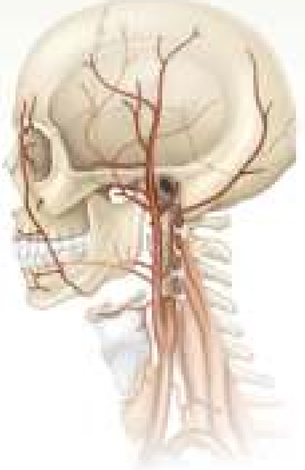
Facts to Remember

- Artery of epistaxis is sphenopalatine.
- Upper few mm of lateral wall of nose and septum of nose are lined by olfactory epithelium with bipolar neurons in it.
- Most of the nerves and blood vessels to the lateral wall of nose and septum of nose are common. The difference is in their magnitude.
- Maxillary sinusitis is the commonest chronic sinusitis.
- Into the middle meatus of nose drain 4 sets of air sinuses.
- Sinusitis may occur due to air pollution.
- Pterygopalatine ganglion is the ganglion of 'hay fever'. It gives secretomotor fibres to lacrimal, nasal, palatal and pharyngeal glands.
- Pain of maxillary sinusitis is referred to upper teeth; of ethmoidal sinusitis to medial side of orbit and of frontal sinusitis to forehead.

BDC's Anatomy *e*-book

1. Summary of pterygopalatine fossa
2. Further reading
3. Viva voce questions

Chapter 16



Larynx

Larynx is a part of upper respiratory tract (Latin *wind pipe*). It is an organ of phonation or voice box. It acts as a sphincter that protects the lower respiratory tract from entry of foreign bodies.

Functions of larynx

1. Air passage
2. Phonation
3. Protective sphincter
4. Deglutition.

Note: The upper respiratory passages include the nose, the nasopharynx and the oropharynx.
One speaks during the expiratory phase of respiration.

Location and Extent

The larynx lies in the anterior midline of the neck, extending from the root of the tongue to the trachea. In the adult male, it lies in front of the 3rd to 6th cervical vertebrae, but in children and in the adult female, it lies at a little higher level (at C1–C4 level) (Plate 16.1, Flowchart 16.1).

Size

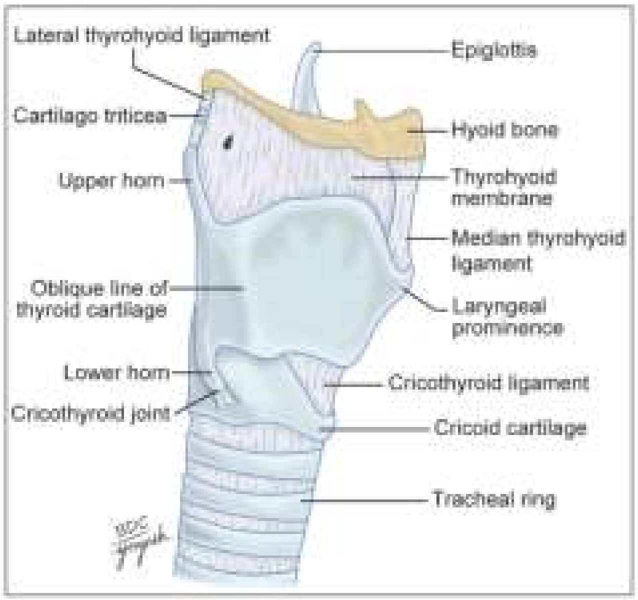
The measurements of larynx are as follows:

Length (vertical):	44 mm in males and 36 mm in females
Transverse:	43 mm in males and 41 mm in females
Anteroposterior:	36 mm in males and 26 mm in females.

Note: At puberty, the male larynx grows rapidly and becomes larger, seen as prominent angle of thyroid cartilage (Adam's apple); which makes his voice louder and low pitched. The pubertal growth of the female larynx is negligible, and her voice is high pitched. Internal diameter—up to 3 years, it is 3 mm; and in an adult, it is 12 mm.

Competency:
AN38.1 Describe the morphology, identify structure of the wall, nerve supply, blood supply and actions of intrinsic and extrinsic muscles of the larynx.

Plate 16.1: Skeleton of the larynx (lateral view)


Lateral thyrohyoid ligament
Epiglottis
Cartilago triticea
Hyoid bone
Upper horn
Thyrohyoid membrane
Median thyrohyoid ligament
Oblique line of thyroid cartilage
Laryngeal prominence
Lower horn
Cricothyroid ligament
Cricothyroid joint
Cricoid cartilage
Tracheal ring
BDC gyanesh

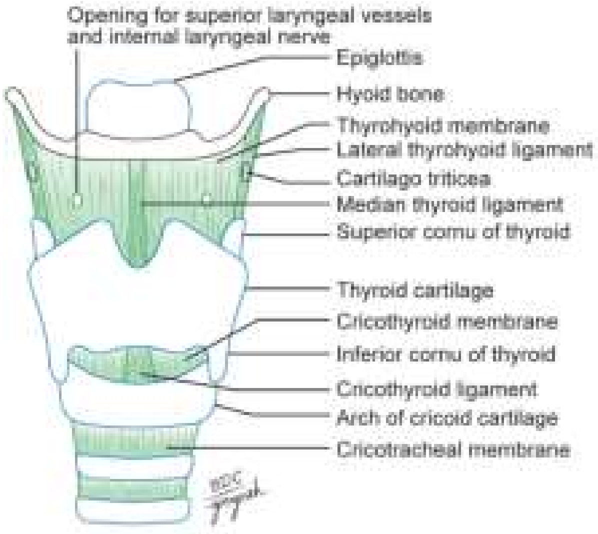
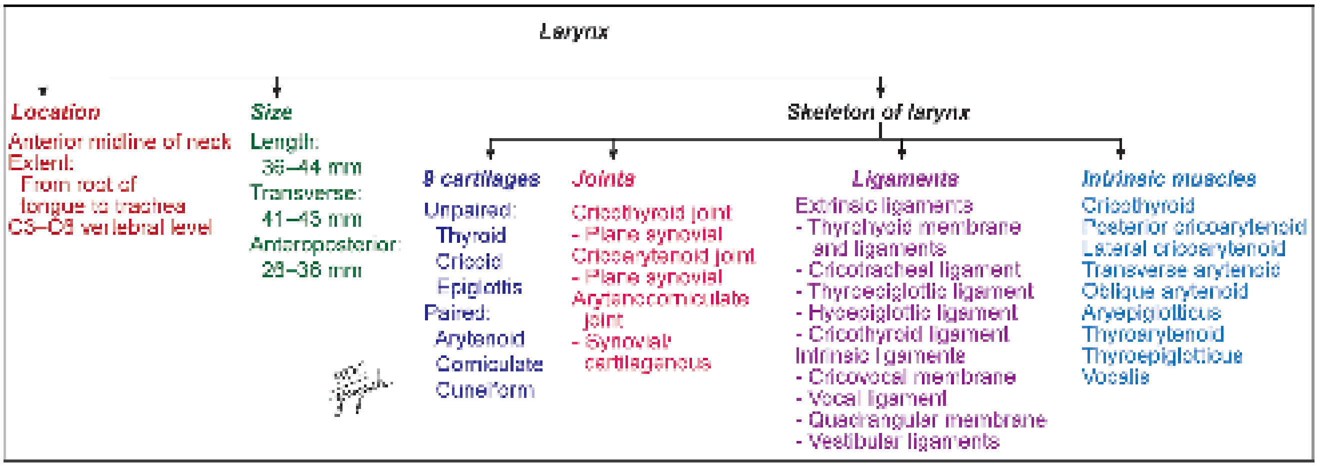

Opening for superior laryngeal vessels and internal laryngeal nerve
Epiglottis
Hyoid bone
Thyrohyoid membrane
Lateral thyrohyoid ligament
Cartilago triticea
Median thyroid ligament
Superior cornu of thyroid
Thyroid cartilage
Cricothyroid membrane
Inferior cornu of thyroid
Cricothyroid ligament
Arch of cricoid cartilage
Cricotracheal membrane
BDC gyanesh

Fig. 16.1: Cartilages and skeleton of larynx (anterior view)

CONSTITUTION OF LARYNX

The larynx is made up of a skeletal framework of cartilages (Plate 16.1 and Fig. 16.1). The cartilages are connected by joints, ligaments and membranes; and are moved by a number of muscles. The cavity of the larynx is lined by mucous membrane.


Flowchart 16.1: Larynx
Larynx
Location
Anterior midline of neck
Extent:
From root of
tongue to trachea
C3–C6 vertebral level
Size
Length:
36–44 mm
Transverse:
41–45 mm
Anteroposterior:
26–36 mm
Skeleton of larynx
9 cartilages
Unpaired:
Thyroid
Cricoid
Epiglottis
Paired:
Arytenoid
Corniculate
Cuneiform
Joints
Cricothyroid joint
- Plane synovial
Cricoarytenoid joint
- Plane synovial
Arytenocorniculate
joint
- Synovial/
cartilaginous
Ligaments
Extrinsic ligaments
- Thyrohyoid membrane
and ligaments
- Cricotracheal ligament
- Thyroepiglottic ligament
- Hyoepiglottic ligament
- Cricothyroid ligament
Intrinsic ligaments
- Cricovocal membrane
- Vocal ligament
- Quadrangular membrane
- Vestibular ligaments
Intrinsic muscles
Cricothyroid
Posterior cricoarytenoid
Lateral cricoarytenoid
Transverse arytenoid
Oblique arytenoid
Aryepiglotticus
Thyroarytenoid
Thyroepiglotticus
Vocalis

CARTILAGES OF LARYNX

The larynx contains nine cartilages, of which three are unpaired and three are paired (Plate 16.1 and Fig. 16.1).

Unpaired cartilages

1. Thyroid (Greek *shield-like*)
2. Cricoid (Greek *ring-like*)
3. Epiglottis (Greek *leaf-like*)

Paired cartilages

1. Arytenoid (Greek *cup-shaped*)
2. Corniculate (Latin *horn-shaped*)
3. Cuneiform (Latin *wedge-shaped*)

Thyroid Cartilage

1. This cartilage is V-shaped in cross-section. It consists of right and left laminae (Plate 16.2 and Fig. 16.1).
2. Each lamina is roughly quadrilateral. The laminae are placed obliquely relative to the midline, their posterior borders are far apart, but the anterior borders approach each other at an angle that is about 90° in the male and about 120° in the female.
3. The lower parts of the anterior borders of the right and left laminae fuse and form a median projection called the ***laryngeal prominence*** or ***Adam's apple***. The upper parts of the anterior borders are separated by the ***thyroid notch***.
4. The posterior borders are free. They are prolonged upwards and downwards as the ***superior and inferior cornua*** or horns. The *inferior cornua* articulates with the cricoid cartilage to form the ***cricothyroid joint*** (Fig. 16.2).
5. The ***outer surface*** of each lamina is marked by an ***oblique line***.

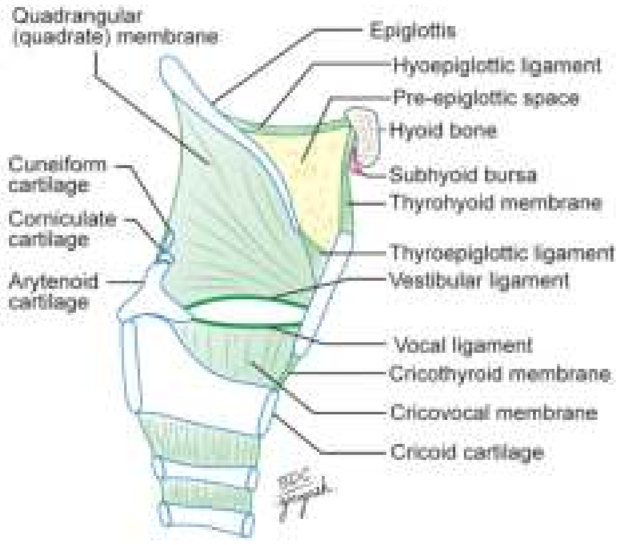

Quadrangular
(quadrate) membrane
Epiglottis
Hyoepiglottic ligament
Pre-epiglottic space
Hyoid bone
Cuneiform
cartilage
Subhyoid bursa
Thyrohyoid membrane
Corniculate
cartilage
Thyroepiglottic ligament
Arytenoid
cartilage
Vestibular ligament
Vocal ligament
Cricothyroid membrane
Cricovocal membrane
Cricoid cartilage

Fig. 16.2: Ligaments and membranes of larynx (sagittal section)

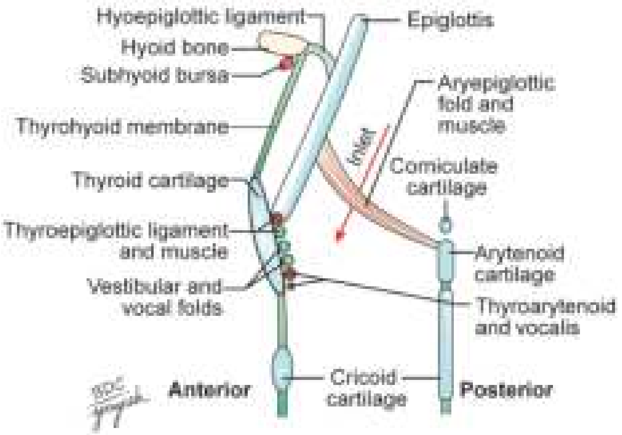
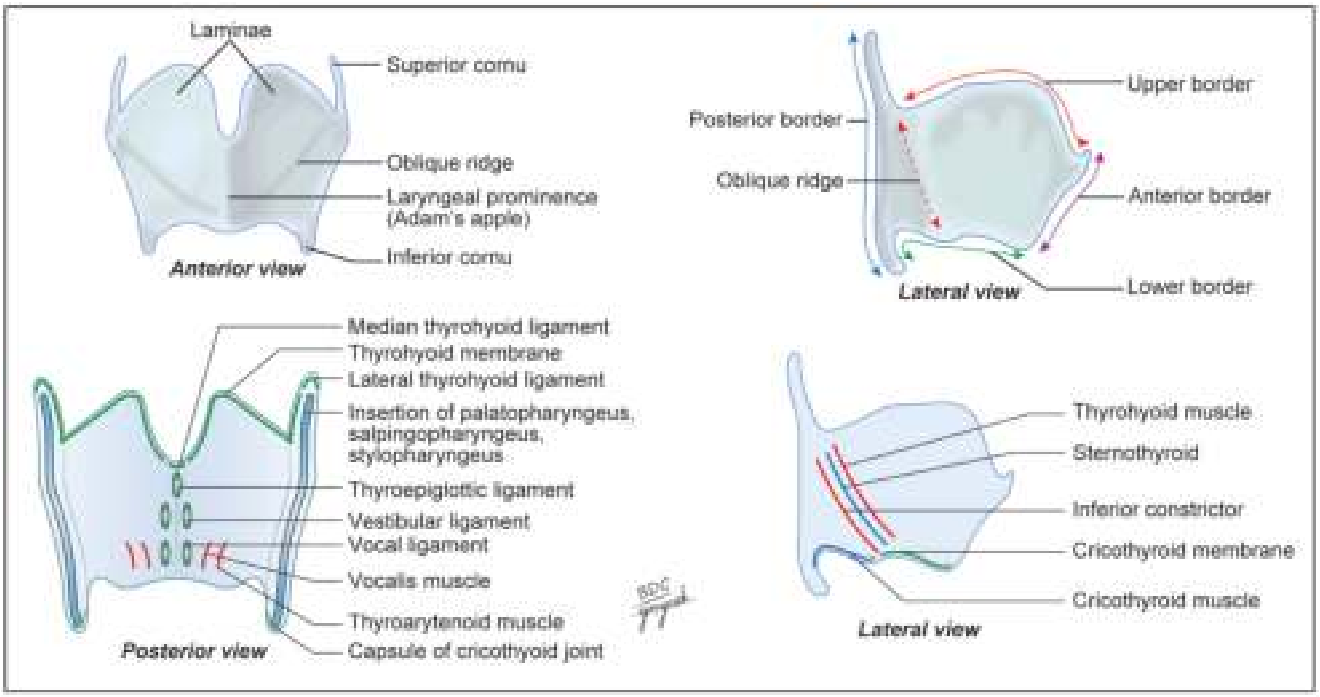

Hyoepiglottic ligament
Epiglottis
Hyoid bone
Subhyoid bursa
Aryepiglottic
fold and
muscle
Thyrohyoid membrane
Inlet
Corniculate
cartilage
Thyroid cartilage
Thyroepiglottic ligament
and muscle
Arytenoid
cartilage
Vestibular and
vocal folds
Thyroarytenoid
and vocalis
Anterior
Cricoid
cartilage
Posterior

Fig. 16.3: Cartilages of the larynx as seen in sagittal section

Attachments (Figs 16.2 and 16.3)

1. Oblique line on the outer surface gives attachments to the following muscles:
   a. *Thyrohyoid*
   b. *Sternothyroid*
   c. Thyropharyngeus part of *inferior constrictor* of pharynx
2. Lower border and inferior cornua give insertion to triangular *cricothyroid*.
3. Along the posterior border connecting superior and inferior cornua are the insertion of the following muscles:
   a. *Palatopharyngeus*

Plate 16.2: Thyroid cartilage


Laminae
Superior cornu
Oblique ridge
Laryngeal prominence (Adam's apple)
Inferior cornu
Anterior view
Posterior border
Oblique ridge
Upper border
Anterior border
Lower border
Lateral view
Median thyrohyoid ligament
Thyrohyoid membrane
Lateral thyrohyoid ligament
Insertion of palatopharyngeus, salpingopharyngeus, stylopharyngeus
Thyroepiglottic ligament
Vestibular ligament
Vocal ligament
Vocalis muscle
Thyroarytenoid muscle
Capsule of cricothyoid joint
Posterior view
Thyrohyoid muscle
Sternothyroid
Inferior constrictor
Cricothyroid membrane
Cricothyroid muscle
Lateral view

   - b. *Salpingopharyngeus*
   - c. *Stylopharyngeus*.
4. On inner aspect are attached:
   - a. Thyroepiglottic ligament
   - b. Thyroepiglottic muscle on each side
   - c. Vestibular ligament/fold on each side
   - d. Vocal ligament/fold on each side
   - e. Thyroarytenoid muscle
   - f. Vocalis muscle on each side.
5. The *superior cornua* is connected with the greater cornua of the hyoid bone by the lateral *thyrohyoid ligament*. Thyrohyoid ligament contains 2 nodules of elastic cartilage known as "***cartilage tritiate***" which may strengthen this connection (refer to Gray's Anatomy, 42nd edition).
6. In the median plane, ***inferior cornua*** is connected to the cricoid cartilage by the ***conus elasticus***.

Cricoid Cartilage

1. Cricoid cartilage is ring-shaped. The ring has a narrow anterior part called the *arch*, and a broad posterior part, called the *lamina* (Plate 16.3).
2. The ***lamina*** projects upwards behind the thyroid cartilage, and articulates superiorly with the arytenoid cartilages.
3. The inferior cornua of the thyroid cartilage articulates with the side of the cricoid cartilage at the junction of the arch and lamina.

Attachments

1. Anterior part of arch of cricoid gives origin to triangular *cricothyroid muscle*, a tensor of vocal cord.
2. Anterolateral aspect of arch gives origin to *lateral cricoarytenoid muscle*, an adductor of vocal cord.
3. Lamina of cricoid cartilage on its outer aspects gives origin to a very important 'safety muscle', the *posterior cricoarytenoid* muscle. *Cricothyroid* and *quadrate membranes* are also attached.

Epiglottic Cartilage/Epiglottis

1. This is a *leaf-shaped* cartilage placed in the anterior wall of the upper part of the larynx (Plate 16.4).
2. Its *upper end* is broad and free, and projects upwards behind the hyoid bone and the tongue.
3. The *lower end* is pointed and is attached to the upper part of the angle between the two laminae of the thyroid cartilage by *thyroepiglottic ligament*.

Attachments

1. The right and left margins of the cartilage provide attachment to the ***aryepiglottic folds***.
2. Its *anterior surface* is connected:
   - a. To the tongue by a median ***glossoepiglottic fold***
   - b. To the hyoid bone by the *hyoepiglottic ligament*.
3. The *posterior surface* is covered with mucous membrane, and presents a tubercle in the lower part.
4. *Thyroepiglottic muscle* is attached between thyroid cartilage and margins of epiglottis. It keeps the inlet of larynx patent for breathing.
5. *Aryepiglottic muscle* closes inlet during swallowing.

Arytenoid Cartilage

1. These are two small *pyramid-shaped* cartilages lying on the upper border of the lamina of the cricoid cartilage (Plate 16.5).
2. The *apex* of the arytenoid cartilage is curved posteromedially and articulates with the corniculate cartilage.

Plate 16.3: Cricoid cartilage

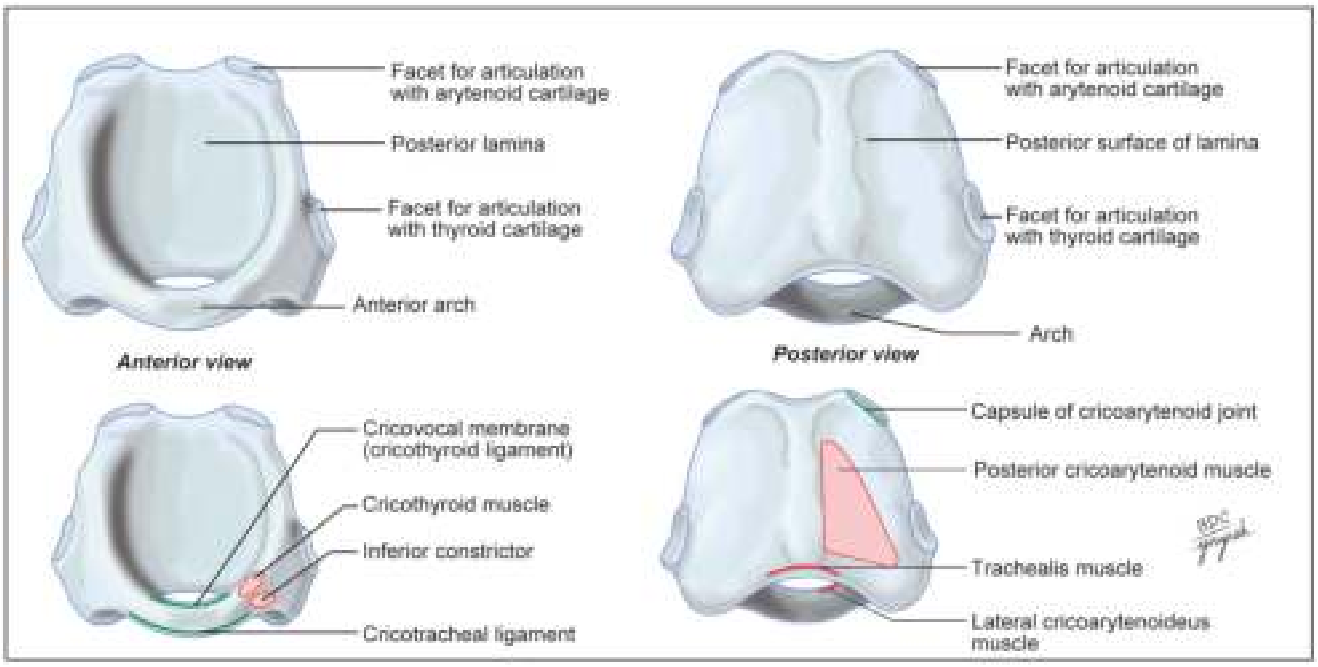

Facet for articulation with arytenoid cartilage
Posterior lamina
Facet for articulation with thyroid cartilage
Anterior arch
Anterior view
Facet for articulation with arytenoid cartilage
Posterior surface of lamina
Facet for articulation with thyroid cartilage
Arch
Posterior view
Cricovocal membrane (cricothyroid ligament)
Cricothyroid muscle
Inferior constrictor
Cricotracheal ligament
Capsule of cricoarytenoid joint
Posterior cricoarytenoid muscle
Trachealis muscle
Lateral cricoarytenoideus muscle

Plate 16.4: Epiglottic cartilage

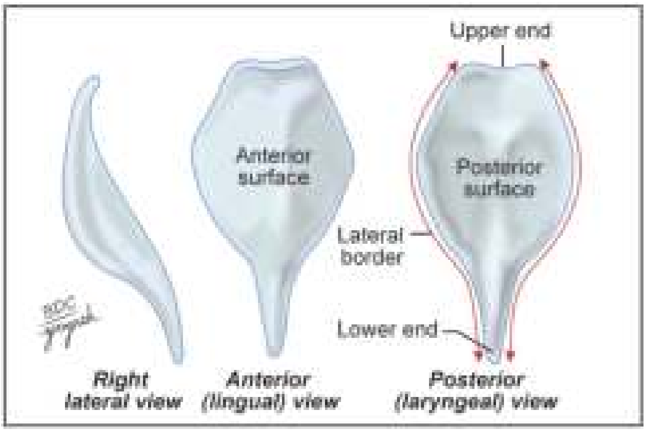
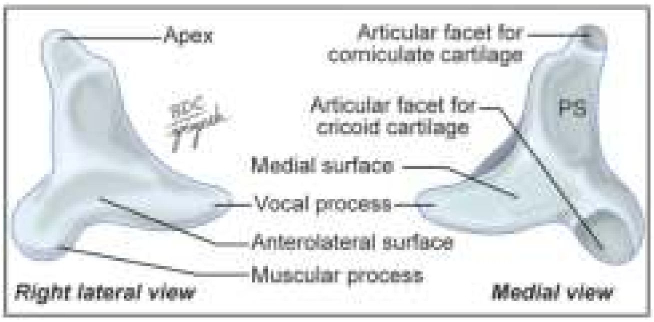

Upper end
Anterior surface
Posterior surface
Lateral border
Lower end
Right lateral view
Anterior (lingual) view
Posterior (laryngeal) view

Plate 16.5: Arytenoid cartilage


Apex
Articular facet for corniculate cartilage
Articular facet for cricoid cartilage
PS
Medial surface
Vocal process
Anterolateral surface
Muscular process
Right lateral view
Medial view

(PS: Posterior surface)

3. Its *base* is concave and articulates with the lateral part of the upper border of the cricoid lamina. Base is prolonged anteriorly to form the ***vocal process***, and laterally to form the ***muscular process***.
4. The *surfaces* of the cartilage are anterolateral, medial and posterior (Plate 16.5).

Attachments

1. ***Vocal process:*** Vocal fold and vocalis muscle is attached.
2. ***Above vocal process:*** Vestibular fold attached.
3. ***Muscular process:*** Posterior aspect gives insertion to *posterior cricoarytenoid*.
4. Anterior aspect gives insertion to lateral *cricoarytenoid*.
5. ***Posterior surface:*** Transverse arytenoid across the two cartilages.
6. Between base and apex of arytenoid is *oblique arytenoid* which continues as *aryepiglottic muscle* into two sides of epiglottis.
7. Quadrangular or *quadrate membrane* is attached between arytenoid, epiglottis and thyroid cartilages.

Corniculate/Santorini Cartilages

These are two small conical nodules which articulate with the apex of the arytenoid cartilages, and are directed posteromedially. They lie in the posterior parts of the aryepiglottic folds.

Cuneiform/Wrisberg Cartilages

These are two small rod-shaped pieces of cartilage placed in the aryepiglottic folds just ventral to the corniculate cartilages.

TYPES OF LARYNGEAL CARTILAGES

The thyroid, cricoid cartilages, and the basal parts of the arytenoid cartilages are made up of the hyaline cartilage. They may ossify after the age of 25 years. The other cartilages of the larynx, e.g. epiglottis, corniculate, cuneiform and processes of the arytenoid are made of the elastic cartilage and do not ossify.

DISSECTION

Identify sternothyroid muscle in the sagittal section of head and neck and define its attachments on the thyroid cartilage. Define the attachments of inferior constrictor muscle from both cricoid and thyroid cartilages including the fascia overlying the cricothyroid muscle.

Cut through the inferior constrictor muscle to locate articulation of inferior horn of thyroid cartilage with cricoid cartilage, i.e. cricothyroid joint. Define the median cricothyroid ligament.

Identify thyrohyoid muscle. Remove this muscle to identify thyrohyoid membrane. Identify superior laryngeal vessels and internal laryngeal nerve piercing this membrane. Identify epiglottis, thyroepiglottic and hyoepiglottic ligaments.

Strip the mucous membrane from the posterior surfaces of arytenoid and cricoid cartilages. Identify posterior cricoarytenoid, transverse arytenoid and oblique arytenoid muscles.

Recurrent laryngeal nerve was seen to enter larynx deep to the inferior constrictor muscle.

Identify cricothyroid muscle, which is the only intrinsic muscle of larynx placed on the external aspect of larynx. Remove the lower half of lamina of thyroid cartilage including the inferior horn of thyroid cartilage. Visualise the thyroarytenoid muscle in the vocal fold.

LARYNGEAL JOINTS

1. The ***cricothyroid joint*** is a *synovial* joint between the inferior cornua of the thyroid cartilage and the side of the cricoid cartilage. It permits rotatory movements around a transverse axis passing through both cricothyroid joints permitting tension and relaxation of vocal cords. There are some gliding movements also in different directions.
2. The ***cricoarytenoid joint*** is also a *synovial* joint between the base of the arytenoid cartilage and the upper border of the lamina of the cricoid cartilage. It permits rotatory movements around a vertical axis permitting adduction and abduction of the vocal cords and also gliding movements in all directions.

LARYNGEAL LIGAMENTS AND MEMBRANES

Extrinsic (Figs 16.2, 16.4 and 16.5)

1. ***Thyrohyoid membrane*** connects the thyroid cartilage to the hyoid bone. Its median and lateral parts are thickened to form the ***median and lateral thyrohyoid ligaments***.

Note:

The membrane is pierced by the internal laryngeal nerve, and by the superior laryngeal vessels.

Tritiate cartilages are small nodules of elastic cartilage present in the free posterior edge of thyrohyoid membrane. These serve to strengthen the connection between superior cornua of thyroid cartilage and tip of greater cornua of hyoid bone.

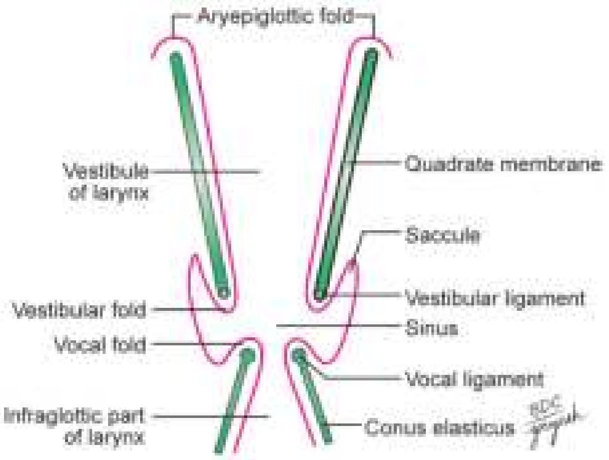

Aryepiglottic fold
Vestibule of larynx
Quadrate membrane
Saccule
Vestibular fold
Vestibular ligament
Sinus
Vocal fold
Vocal ligament
Infraglottic part of larynx
Conus elasticus

Fig. 16.4: Coronal section showing parts of cavity of the larynx

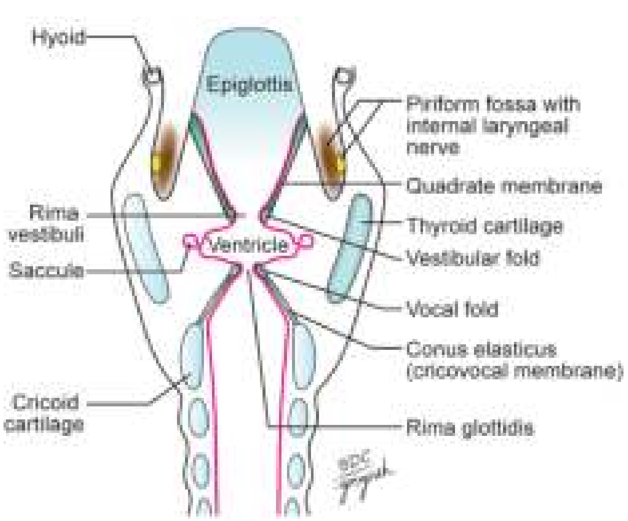

Hyoid
Epiglottis
Piriform fossa with internal laryngeal nerve
Quadrate membrane
Rima vestibuli
Thyroid cartilage
Ventricle
Vestibular fold
Saccule
Vocal fold
Conus elasticus (cricovocal membrane)
Cricoid cartilage
Rima glottidis

Fig. 16.5: Cavity of larynx and position of piriform fossa

2. ***Hyoepiglottic ligament*** connects the upper end of the epiglottic cartilage to the hyoid bone.
3. ***Cricotracheal ligament*** connects the cricoid cartilage to the upper end of the trachea.

Intrinsic (Figs 16.2, 16.4 and 16.5)

1. The intrinsic ligaments are part of a broad sheet of fibroelastic tissue, known as the ***fibroelastic membrane of the larynx***. This membrane is placed just outside the mucous membrane. It is interrupted on each side by the sinus of the larynx. The part of the membrane above the sinus is known as the ***quadrate membrane***, and the part below the sinus is called the ***conus elasticus*** (Fig. 16.4).
2. ***Quadrate membrane*** extends from the arytenoid cartilage to the epiglottis. It has a lower free border which forms the *vestibular fold* and an upper border which forms the *aryepiglottic fold*.
3. ***Conus elasticus*** or ***cricovocal membrane*** extends upwards and medially from the arch of the cricoid cartilage. The anterior part is thick and is known as the ***cricothyroid ligament***. The upper free border of the conus elasticus forms the *vocal fold* (Fig. 16.5).

CAVITY OF LARYNX

The cavity of the larynx extends from the inlet of larynx to the lower border of the cricoid cartilage (Plate 16.6 and Flowchart 16.2).

Communications

1. Above the larynx, communicates with laryngopharynx through the *laryngeal inlet*. Below the larynx, continues with the trachea at the lower border of cricoid cartilage.
2. *Laryngeal inlet* is placed obliquely, sloping downward and backwards.

   Boundaries

   Anterior: Epiglottis

   Posterior: Interarytenoid fold of mucous membrane

   Lateral (on each side): Aryepiglottic fold of mucous membrane.
3. *Vestibular and vocal folds:* The cavity of larynx shows two mucosal folds on each side as follows:
   1. Upper *vestibular* (*false vocal*) *folds* are produced by vestibular ligaments.
   2. Lower *vocal* (*true vocal*) *folds* are produced by vocal ligament and vocalis muscle. They extend from the middle of the thyroid angle to the vocal process of arytenoid cartilage.
4. *Rima vestibuli* and *rima glottidis: The rima vestibuli* is a space (gap) between the right and left vestibular folds. *The rima glottidis* is a space (gap) between the right and left vocal folds. It is the narrowest part of larynx.

Subdivisions of Laryngeal Cavity

The laryngeal cavity is divided into three parts by two pairs of vestibular and vocal folds:

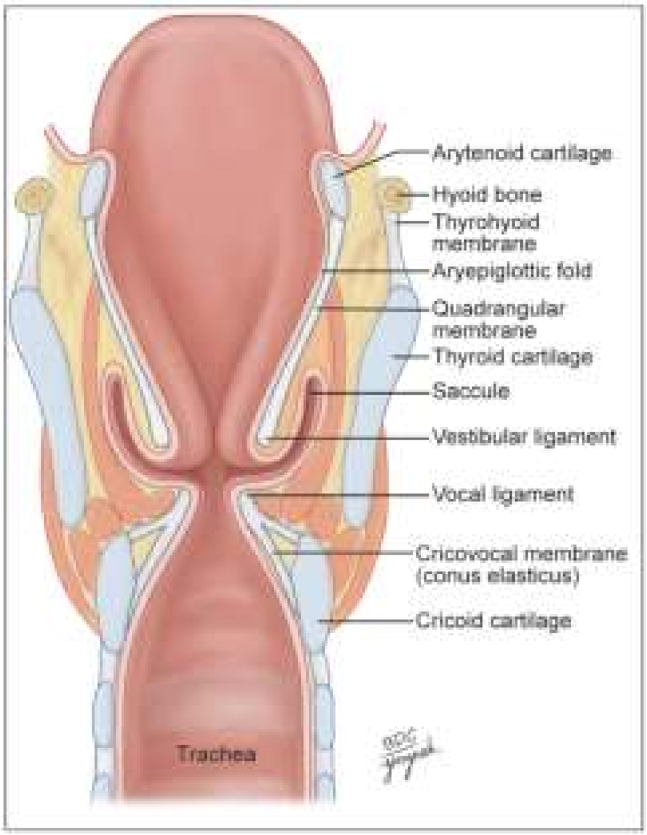
1. *Vestibule* (*supraglottic compartment*): It extends from the laryngeal inlet to the vestibular folds.
2. *Ventricle or sinus of larynx* (*glottic compartment*): It is an elliptical space that extends from vestibular folds to vocal folds.
3. *Infraglottic compartment*: It extends from vocal folds to the lower border of cricoid cartilage.

Saccule of Larynx

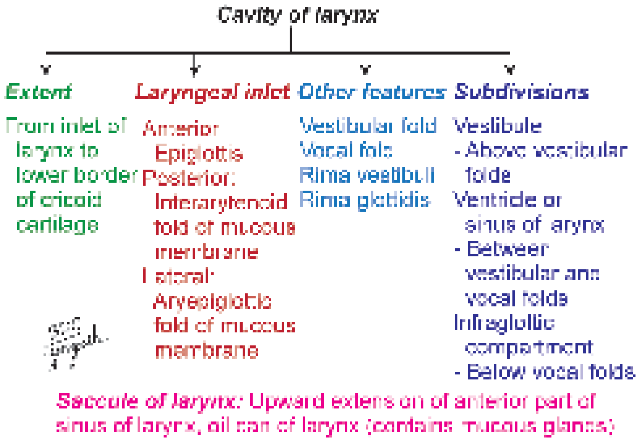
The anterior part of sinus of larynx extends upward as a diverticulum between the vestibular folds and lamina of thyroid cartilage. This extension is known as *saccule of larynx* (Plate 16.6).

Note: **Oil can of larynx:** The saccule contains mucous glands which lubricates the vocal folds. Hence, the saccule is also termed as oil can of larynx.

Plate 16.6: Interior of the larynx (coronal section of the laryngeal cavity)


Arytenoid cartilage
Hyoid bone
Thyrohyoid membrane
Aryepiglottic fold
Quadrangular membrane
Thyroid cartilage
Saccule
Vestibular ligament
Vocal ligament
Cricovocal membrane (conus elasticus)
Cricoid cartilage
Trachea

Flowchart 16.2: Cavity of larynx


Cavity of larynx
Extent
From inlet of larynx to lower border of cricoid cartilage
Laryngeal inlet
Anterior
Epiglottis
Posterior:
Interarytenoid fold of mucous membrane
Lateral:
Aryepiglottic fold of mucous membrane
Other features
Vestibular fold
Vocal fold
Rima vestibuli
Rima glottidis
Subdivisions
Vestibule
- Above vestibular folds
Ventricle or sinus of larynx
- Between vestibular and vocal folds
Infraglottic compartment
- Below vocal folds

Saccule of larynx: Upward extension of anterior part of sinus of larynx, oil can of larynx (contains mucous glands)

MUCOUS MEMBRANE OF LARYNX

1. The anterior surface and upper half of the posterior surface of the epiglottis, the upper parts of the aryepiglottic folds, and the vocal folds are lined by the *stratified squamous epithelium.* The rest of the laryngeal mucous membrane is covered with the *ciliated columnar epithelium.*
2. The mucous membrane is loosely attached to the cartilages of the larynx except over the vocal ligaments and over the posterior surface of the epiglottis where it is thin and firmly adherent.
3. The *mucous glands* are absent over the vocal cords, but are plentiful over the anterior surface of the epiglottis, around the cuneiform cartilages and in the vestibular folds. The glands are scattered over the rest of the larynx.

Competencies:

AN36.5 Describe the pharyngeal spaces. Also describe the boundaries and clinical significance of pyriform fossa.

AN38.2 Describe the anatomical aspects of laryngitis.

CLINICAL ANATOMY

- Infection of the larynx is called ***laryngitis***. It is characterized by hoarseness of voice.
- ***Laryngeal oedema*** may occur due to a variety of causes. This can obstruct breathing. Inflammation of upper larynx may cause oedema of supraglottis part. It does not extend below vocal cords because mucosa is adherent to vocal ligament.
- Misuse of the vocal cords may produce nodules on the vocal cords mostly at the junction of anterior 1/3rd and posterior 2/3rd. These are called ***Singer's nodules*** or ***Teacher's nodules*** (Fig. 16.6).
- *Fibreoptic flexible **laryngoscopy:*** Under local anaesthesia, flexible laryngoscope is passed and larynx well visualised.
- ***Microlaryngoscopy:*** This procedure is performed under operating microscope. Vocal cord tumours and diseases are excised by this method.
- ***Foreign body in larynx:*** Since the larynx or glottis is the narrowest part of the respiratory passages, ***foreign bodies*** are usually lodged here. Large foreign bodies may block laryngeal inlet leading to suffocation.
- At times fish bones may get impacted in the vallecula or piriform fossa. Often these bones just scratch the mucosa on their way down, and the person gets a feeling of foreign body sensation, due to a dull visceral pain caused by the scratch.
- ***Piriform fossa*** lies between quadrate membrane and medial side of thyroid cartilage. It is traversed by internal laryngeal nerve. Piriform fossa is used to smuggle out precious stones, diamonds, etc. It is called ***smuggler's fossa***.
- The mucous membrane of the larynx is supplied by X nerve through superior laryngeal or recurrent laryngeal nerves. So laryngeal tumours may also cause referred pain in the ear partly supplied by auricular branch of X nerve.

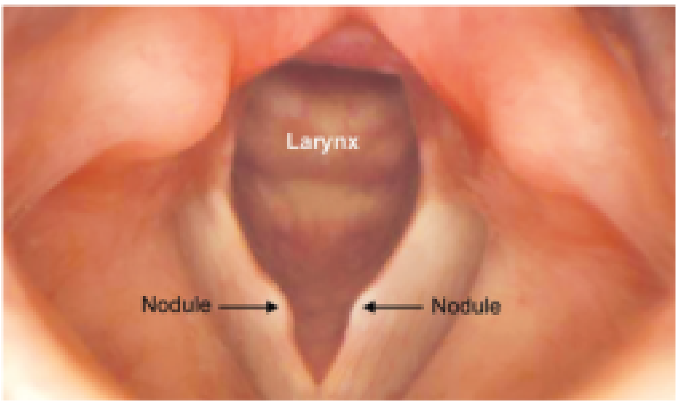


Fig. 16.6: Indirect laryngoscopic examination

MUSCLES OF LARYNX

The muscles of the larynx are grouped as extrinsic and intrinsic muscles (Tables 16.1 and 16.2).

Extrinsic Muscles

These are paired muscles and move the larynx as a whole. They are:

1. Palatopharyngeus
2. Salpingopharyngeus
3. Stylopharyngeus
4. Thyrohyoid
5. Sternothyroid.

These are attached to one of the laryngeal cartilages and adjacent bones.

Intrinsic Muscles

These muscles extend between laryngeal cartilages. They include (Plate 16.7 and Figs 16.7 to 16.9):

1. Cricothyroid
2. Posterior cricoarytenoid
3. Lateral cricoarytenoid
4. Transverse arytenoid
5. Oblique arytenoid
6. Aryepiglotticus
7. Thyroarytenoid
8. Thyroepiglotticus
9. Vocalis.

The intrinsic muscle of larynx:

1. Opens or closes the laryngeal inlet
2. Adducts or abducts the vocal cords
3. Lengthens or shortens the vocal cords
4. Increases or decreases the tension in vocal cords.

Nerve Supply

All intrinsic muscles of the larynx are supplied by the ***recurrent laryngeal nerve*** *except* for the cricothyroid which is supplied by the external laryngeal nerve.

Note:

The vocal and muscular processes move in opposite directions. Any muscle which pulls the muscular process medially, pushes the vocal process laterally, resulting in abduction of vocal cords. This is done by only one pair of muscle, the posterior cricoarytenoid.

Muscles which pull the muscular process forward and laterally will push the vocal process medially causing adduction of vocal cords. This is done by lateral cricoarytenoid and transverse arytenoid.

The cricothyroid causes rocking movement of thyroid forwards and downwards at cricothyroid joints, thus tensing and lengthening the vocal cords.

Muscles which abduct the vocal cords: Only posterior cricoarytenoids (safety muscle of larynx).

MOVEMENTS OF VOCAL FOLDS

Movements of the vocal folds affect the shape and size of the rima glottidis (Figs 16.10 to 16.15).

1. During quiet breathing or condition of rest, the intermembranous part of the rima is triangular, and the intercartilaginous part is quadrangular (Fig. 16.8).

Plate 16.7: Intrinsic muscles of larynx

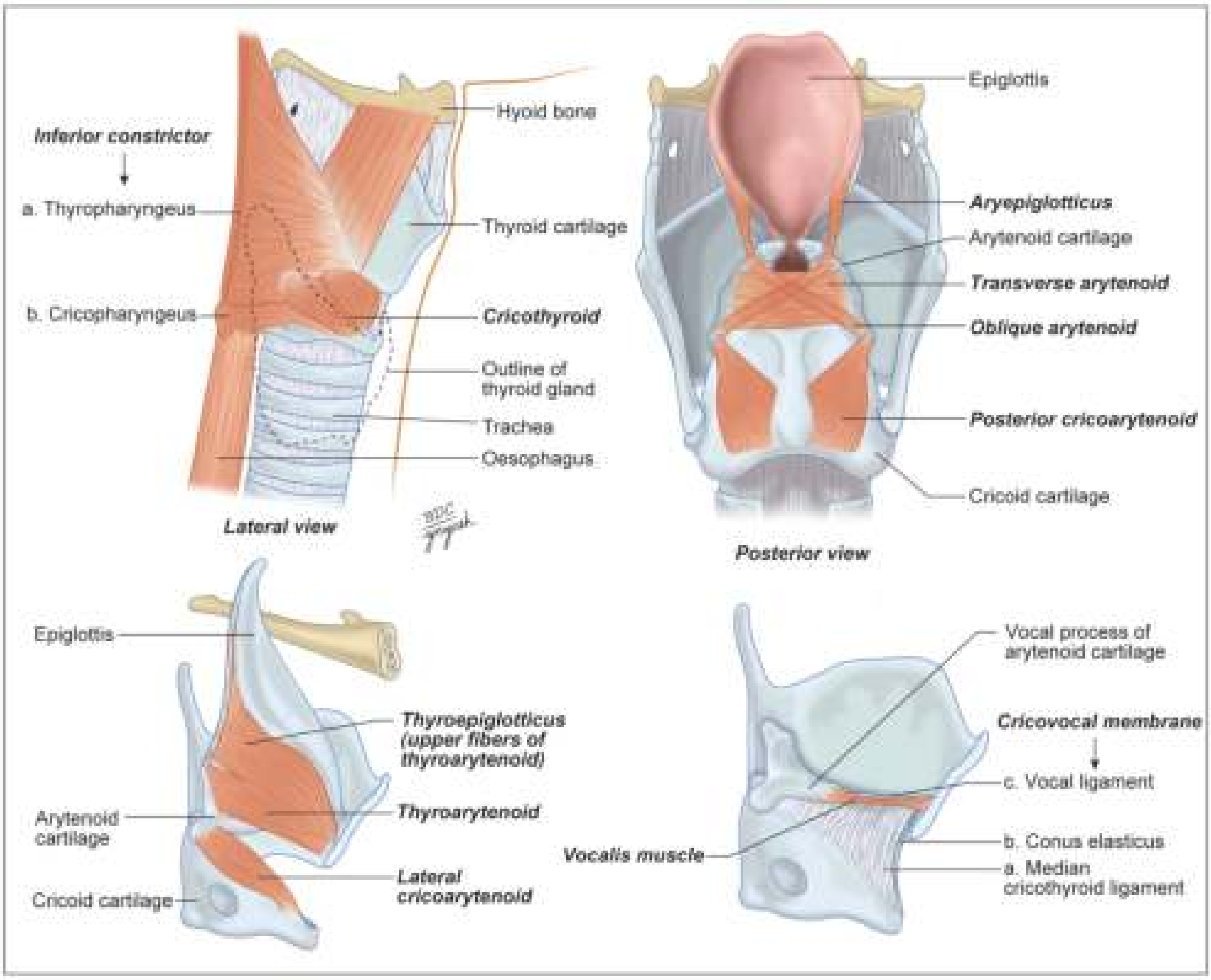
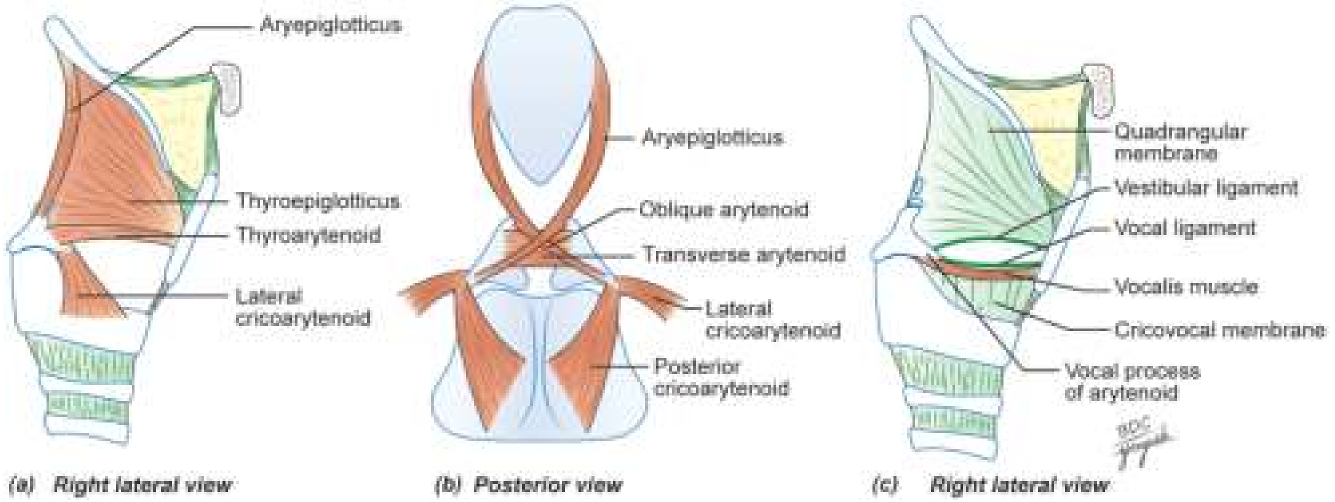

Inferior constrictor
a. Thyropharyngeus
b. Cricopharyngeus
Hyoid bone
Thyroid cartilage
Cricothyroid
Outline of thyroid gland
Trachea
Oesophagus
Lateral view
Epiglottis
Aryepiglotticus
Arytenoid cartilage
Transverse arytenoid
Oblique arytenoid
Posterior cricoarytenoid
Cricoid cartilage
Posterior view
Epiglottis
Thyroepiglotticus (upper fibers of thyroarytenoid)
Thyroarytenoid
Arytenoid cartilage
Cricoid cartilage
Lateral cricoarytenoid
Vocal process of arytenoid cartilage
Cricovocal membrane
c. Vocal ligament
Vocalis muscle
b. Conus elasticus
a. Median cricothyroid ligament

TABLE 16.1: Origin, fibres and insertion of intrinsic muscles of the larynx (Plate 16.7 and Figs 16.7 to 16.9)

Muscle	*Origin*	*Fibres*	*Insertion*
1. **Cricothyroid** The only muscle outside the larynx It is called 'tuning fork of larynx'	Lower border and lateral surface of cricoid cartilage	Fibres pass backwards and upwards	Inferior cornua and lower border of thyroid cartilage
2. **Posterior cricoarytenoid** Triangular	Posterior surface of the lamina of cricoid cartilage	Upwards and laterally	Posterior aspect of muscular process of arytenoid cartilage
3. **Lateral cricoarytenoid**	Upper border of arch of cricoid cartilage	Upwards and backwards	Anterior aspect of muscular process of arytenoid cartilage
4. **Transverse arytenoid** Unpaired muscle	Posterior surface of one arytenoid cartilage	Transverse	Posterior surface of another arytenoid cartilage
5, 6. **Oblique arytenoid** and **aryepiglottic**	Muscular process of one arytenoid cartilage	Oblique	Apex of the other arytenoid. Some fibres are continued as *aryepiglottic* muscle to the edge of the epiglottis
7, 8. **Thyroarytenoid** and **thyroepiglotticus**	Thyroid angle and adjacent cricothyroid ligament	Backwards and upwards	Anterolateral surface of arytenoid cartilage Some of the upper fibres of thyroarytenoid curve upwards into the aryepiglottic fold to reach the edge of epiglottis, known as *thyroepiglotticus*
9. **Vocalis**	Vocal process of arytenoid cartilage	Pass forwards	Vocal ligament and thyroid angle


Aryepiglotticus
Thyroepiglotticus
Thyroarytenoid
Lateral cricoarytenoid
(a) Right lateral view
Aryepiglotticus
Oblique arytenoid
Transverse arytenoid
Lateral cricoarytenoid
Posterior cricoarytenoid
(b) Posterior view
Quadrangular membrane
Vestibular ligament
Vocal ligament
Vocalis muscle
Cricovocal membrane
Vocal process of arytenoid
(c) Right lateral view

Figs 16.7a to c: Intrinsic muscles of the larynx

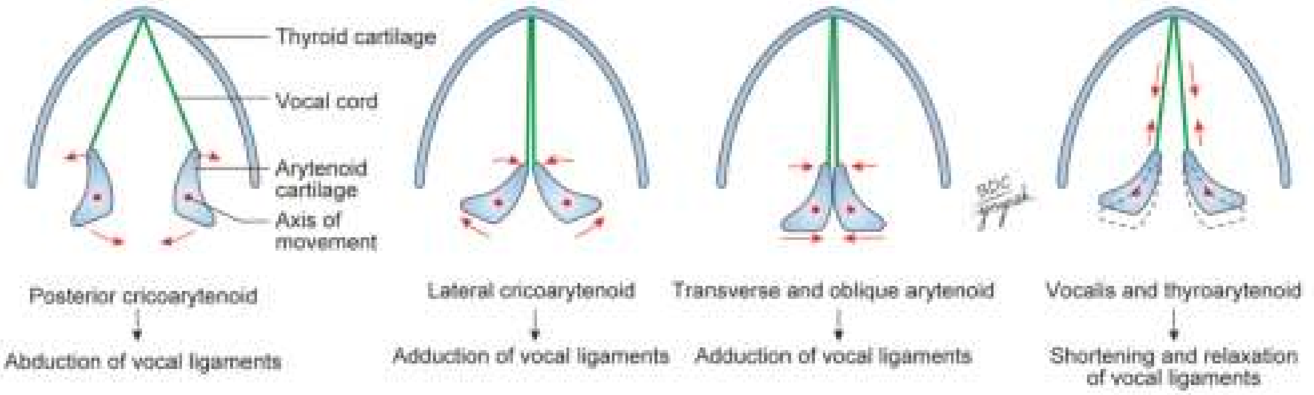

Thyroid cartilage
Vocal cord
Arytenoid cartilage
Axis of movement
Posterior cricoarytenoid
Abduction of vocal ligaments
Lateral cricoarytenoid
Adduction of vocal ligaments
Transverse and oblique arytenoid
Adduction of vocal ligaments
Vocalis and thyroarytenoid
Shortening and relaxation of vocal ligaments

Fig. 16.8: Actions of intrinsic muscles of larynx

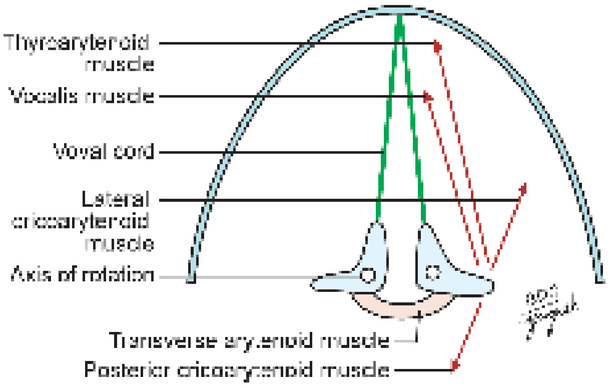

Thyroarytenoid muscle
Vocalis muscle
Vocal cord
Lateral cricoarytenoid muscle
Axis of rotation
Transverse arytenoid muscle
Posterior cricoarytenoid muscle

Fig. 16.9: Scheme to show the direction of pull of some intrinsic muscles of the larynx

2. During phonation or speech, the glottis is reduced to a chink by the adduction of the vocal folds.
3. During forced inspiration, both parts of the rima are triangular, so that the entire rima is lozenge-shaped; the vocal folds are fully abducted (i.e. diamond-shaped glottis).
4. During whispering, the intermembranous part of the rima glottidis is closed, but the intercartilaginous part is widely open(i.e. funnel-shaped glottis).

TABLE 16.2: Muscles acting on the larynx

Movement	*Muscle*
Elevation of larynx	Thyrohyoid, mylohyoid
Depression of larynx	Sternothyroid, sternohyoid
Opening inlet of larynx	Thyroepiglotticus
Closing inlet of larynx	Aryepiglotticus
Abductor of vocal cords	Posterior cricoarytenoid only
Adductor of vocal cords	Lateral cricoarytenoid, transverse and oblique arytenoids
Tensor of vocal cords and modulation of voice (lengthening of vocal cord)	Cricothyroid
Relaxor and adjust tension of vocal cords	Thyroarytenoid and vocalis

BLOOD SUPPLY, NERVE SUPPLY AND LYMPHATIC DRAINAGE OF LARYNX

Arterial Supply and Venous Drainage

Up to the Vocal Folds

By the superior laryngeal artery, a branch of the superior thyroid artery. The superior laryngeal vein drains into the superior thyroid vein.

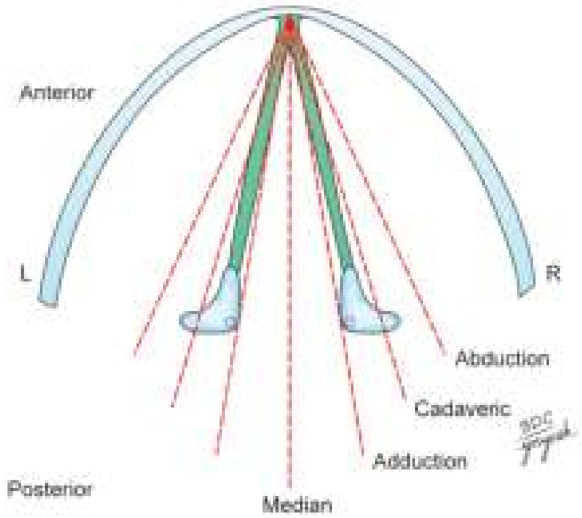
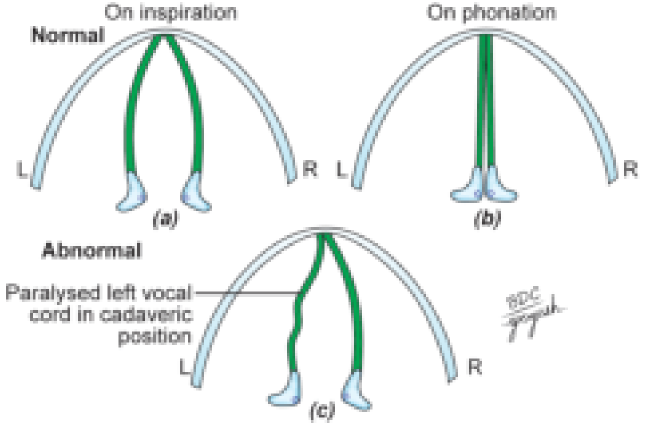

Anterior
L
R
Abduction
Cadaveric
Adduction
Posterior
Median

Fig. 16.10: Various positions of the vocal cords


On inspiration
Normal
On phonation
L
R
L
R
(a)
(b)
Abnormal
Paralysed left vocal cord in cadaveric position
L
R
(c)

Figs 16.11a to c: Position of vocal cords: (a) Inspiration, (b) phonation and (c) abnormal

Below the Vocal Folds

By the inferior laryngeal artery, a branch of the inferior thyroid artery. The inferior laryngeal vein drains into the inferior thyroid vein.

Nerve Supply

Motor Nerves

Recurrent laryngeal nerve supplies posterior cricoarytenoid, lateral cricoarytenoid, transverse and oblique arytenoid, aryepiglottic, thyroarytenoid, thyroepiglottic

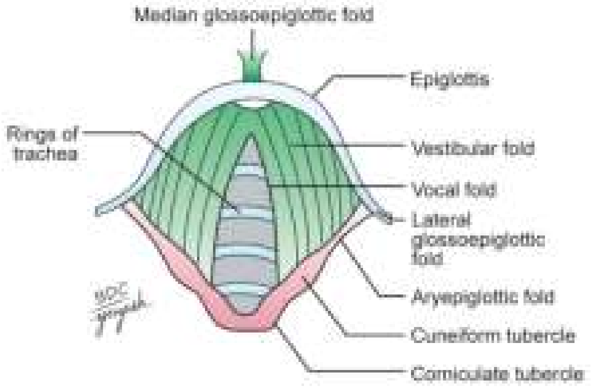

Median glossoepiglottic fold
Epiglottis
Rings of trachea
Vestibular fold
Vocal fold
Lateral glossoepiglottic fold
Aryepiglottic fold
Cuneiform tubercle
Corniculate tubercle

Fig. 16.12: Parts of larynx seen by indirect laryngoscopy

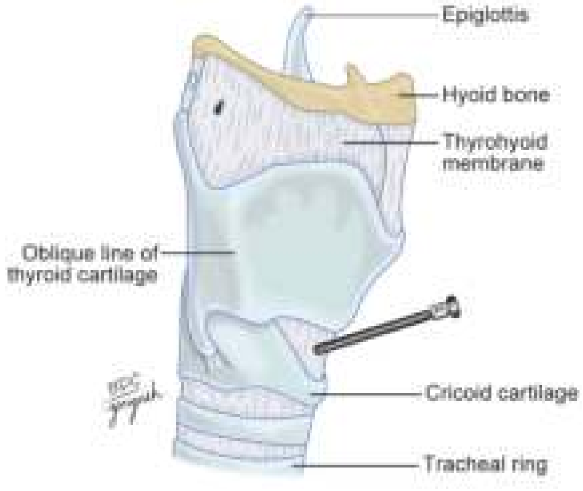

Epiglottis
Hyoid bone
Thyrohyoid membrane
Oblique line of thyroid cartilage
Cricoid cartilage
Tracheal ring

Fig. 16.13: Laryngotomy

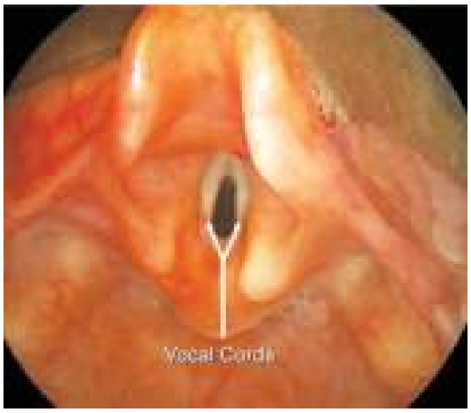

Vocal Cords

Fig. 16.14: Direct laryngoscopic view of vocal cords in adducted position

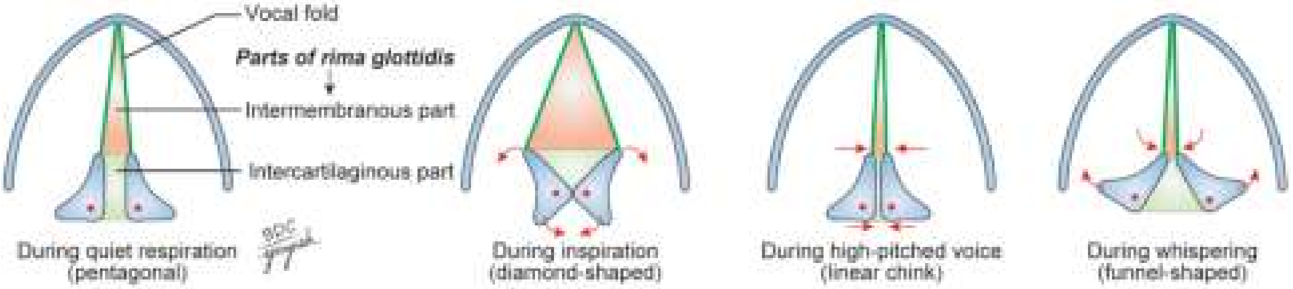

Vocal fold
Parts of rima glottidis
Intermembranous part
Intercartilaginous part
During quiet respiration (pentagonal)
During inspiration (diamond-shaped)
During high-pitched voice (linear chink)
During whispering (funnel-shaped)

Fig. 16.15: Rima glottidis during different movements of the vocal cords

muscles. It supplies all intrinsic muscles except cricothyroid.

External laryngeal nerve only supplies cricothyroid muscle.

Sensory Nerves

The internal laryngeal nerve supplies the mucous membrane up to the level of the vocal folds. The recurrent laryngeal nerve supplies it below the level of the vocal folds.

Lymphatic Drainage

Lymphatics from the part above the vocal folds drain along the superior thyroid vessels to the anterosuperior group of deep cervical nodes by piercing thyrohyoid membrane.

Those from the part below the vocal folds drain to the posteroinferior group of deep cervical nodes. A few of them drain into the prelaryngeal nodes by piercing cricothyroid. True vocal folds, i.e. glottis acts as watershed for lymphatics. It has 'no' lymphatics. Carcinoma of glottis carries best prognosis.

Competency:
AN38.3 Describe anatomical basis of recurrent laryngeal nerve injury.

CLINICAL ANATOMY

- When any foreign object enters the larynx severe protective coughing is excited to expel the object. However, damage to the internal laryngeal nerve produces anaesthesia of the mucous membrane in the supraglottic part of the larynx breaking the reflex arc so that foreign bodies can readily enter it.
- Damage to the external laryngeal nerve causes some weakness of phonation due to loss of the tightening effect of the cricothyroid on the vocal cord.
- When both recurrent laryngeal nerves are interrupted, the vocal cords lie in the cadaveric position in between abduction and adduction, and phonation is completely lost. Deep breathing also becomes difficult through the partially opened glottis.
- When only one recurrent laryngeal nerve is paralysed, the opposite vocal cord compensates for it and phonation is possible but there is hoarseness of voice. There is failure of forceful explosive part of voluntary and reflex coughing.
- Tumours in the piriform fossa cause dysphagia. These also cause referred pain in the ear. Pain of pharyngeal tumours may be referred to the ear, as X nerve carries sensation both from the pharynx and the external auditory meatus and the tympanic membrane.
- *Recurrent laryngeal nerve:* Mediastinal tumours may press on the left recurrent laryngeal nerve, as it is given off in the thorax. The pressure on the nerve may present as alteration in the voice. Right recurrent laryngeal nerve is given off in the neck, so it is not affected by mediastinal tumours.
- The larynx can be examined either directly through a laryngoscope or indirectly through a laryngeal mirror (indirect laryngoscopy) (Fig. 16.14).
- By laryngoscopy, one can inspect the base of the tongue, the valleculae, the epiglottis, the aryepiglottic folds, the piriform fossae, the vestibular folds, and the vocal folds.
- Tumours of the vocal cords can be diagnosed early, because there are changes in the voice. Tumours in subglottic area present late so are diagnosed late and have poor prognosis.
- ***Laryngotomy:*** The needle is inserted in the midline of cricothyroid membrane, below the thyroid prominence. This is done as an emergency procedure.

INFANT'S LARYNX

Cavity of infant's larynx is short and funnel-shaped.

- Size is one-third of an adult. Lumen is very narrow.
- Position is higher than in adult.
- Epiglottis lies at C2 and during elevation, it reaches C1, so that infant can use nasal airway for breathing while suckling.
- Laryngeal cartilages are softer, more pliable than in adult.
- Thyroid cartilage is shorter and broader.
- Vocal cords are only 4–4.5 mm long, shorter than in childhood and in adult.
- Supraglottic and subglottic mucosa are lax, swelling results in respiratory obstruction.
- One must be careful while giving anaesthesia to an infant (birth to one year).

MECHANISM OF SPEECH

The mechanism of speech involves the following four processes:

- Expired air from lungs
- Vibrators
- Resonators
- Articulators

Expired Air

As the air is forced out of lungs and larynx, it produces voice. Loudness or intensity of voice depends on the force of expiration of air.

Vibrators

The expired air causes vibrations of the vocal cords. Pitch of voice depends on the rate of vibration of vocal cords. Vowels are produced in the larynx.

Resonators

The column of air between vocal cords and nose and lips act as resonators. Quality of sound depends on resonators. One can make out change of quality of voice even on the telephone.

Articulators

These are formed by palate, tongue, teeth and lips. These narrow or stop the exhaled air. Vowels are produced due to vibrations of vocal cords. Many of the consonants are produced by the intrinsic muscles of tongue. Consonants produced by lips are:

Pa, Pha, Ba, Bha, Ma

Labiodental—Ta, Tha, Da, Dha, Na

Lingual—Cha, Ja, Jha

Palatal—Ka, Kha, Ga, Gha.

VIDEO

Video 3.16 Larynx

Facts to Remember

- Only intrinsic muscle of larynx placed on the outer aspect of laryngeal cartilages is cricothyroid.
- Cricothyroid is the only muscle supplied by external laryngeal nerve.
- External laryngeal nerve runs with superior thyroid artery. Near the apex of the lobe, it deviates medially to supply inferior constrictor and cricothyroid muscles.
- Posterior cricoarytenoid is the only abductor of vocal cord and so it is a life-saving muscle.
- Tuning fork of larynx (chief tensor of vocal cords) is cricothyroid.
- Piriform fossa is called smuggler's fossa as precious stones, etc. can be hidden here.
- The primary function of larynx is to protect the lower respiratory tract. Phonation has developed with evolution and is related to motor speech area of the cerebral cortex.
- Singer's or teacher's nodules are inflammatory nodules on the vocal cords at the junction of anterior one-third and posterior two-third.
- Rima glottidis is the narrowest region of the laryngeal cavity.

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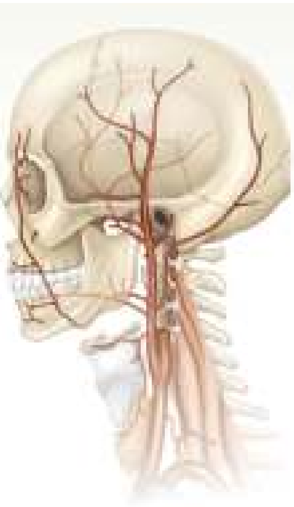
1. Cricothyroid – tuning fork of larynx
2. Posterior cricoarytenoid – safety muscle of larynx
3. Further reading
4. Viva voce questions

Chapter

17



Tongue

The tongue is a muscular organ situated in the floor of the mouth. It is associated with the functions of taste, speech, chewing, deglutition, and cleansing of mouth. The tongue comprises voluntary skeletal muscles.

PARTS OF TONGUE

The tongue has:

1. Root
2. Tip
3. Body

Root

The *root* is a fixed part. It is attached to the styloid process and soft palate above, and to mandible and the hyoid bone below. In between the mandible and hyoid bones, it is related to the geniohyoid and mylohyoid muscles.

Tip

The *tip* of the tongue forms the anterior free end which, at rest, lies behind the upper incisor teeth.

Body

The body of the tongue has:

a. A curved upper surface or *dorsum* (Fig. 17.1), and
b. An inferior surface confined to the oral part only.

The *dorsum* of the tongue (Fig. 17.1) is convex in all directions. It is divided into:

- An *oral part* or anterior two-thirds.
- A *pharyngeal part* or posterior one-third, by a faint V-shaped groove, the ***sulcus terminalis***. The two limbs of the 'V' meet at a median pit, named the ***foramen caecum***. They run laterally and forwards up to the palatoglossal arches.

  Note: The foramen caecum represents the site from which the thyroid diverticulum grows down in the embryo. The oral and pharyngeal parts of the tongue differ in their development, topography, structure, and function.
- Small posteriormost part.

Oral Part

The ***oral or papillary part*** of the tongue is placed on the floor of the mouth. Its *margins* are free and in contact with the gums and teeth. Just in front of the circumvallate papillae, each margin shows 4 to 5 vertical folds, named the ***foliate papillae***.

The *superior surface* of the oral part shows a median furrow and is covered with papillae which make it rough (Fig. 17.1).

The ***inferior surface*** is covered with a smooth mucous membrane, which shows a median fold called the ***frenulum linguae***.

On either side of the frenulum, there is a prominence produced by the deep lingual veins. More laterally, there is a fold called the ***plica fimbriata*** that is directed forwards and medially towards the tip of the tongue (Fig. 17.2).

Pharyngeal Part

The ***pharyngeal or lymphoid part*** *of the tongue* lies behind the palatoglossal arches and the sulcus terminalis. Its posterior surface, sometimes called the base of the tongue, forms the anterior wall of the oropharynx. The mucous membrane has no papillae, but has many *lymphoid follicles* that collectively constitute the ***lingual tonsil***. Mucous glands are also present.

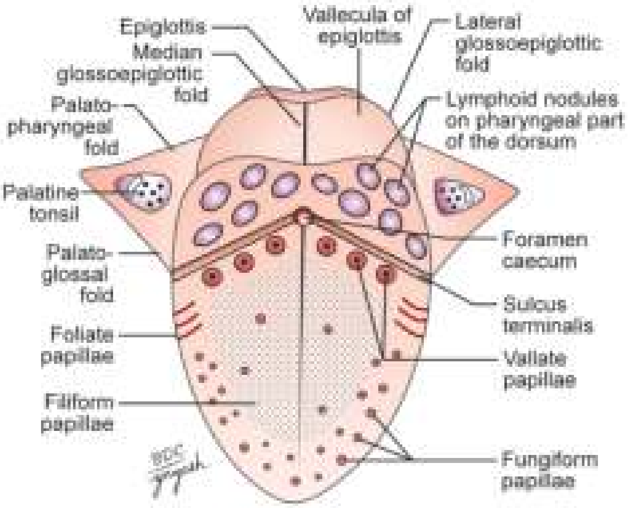

Epiglottis
Median glossoepiglottic fold
Palato-pharyngeal fold
Palatine tonsil
Palato-glossal fold
Foliate papillae
Filiform papillae
Vallecula of epiglottis
Lateral glossoepiglottic fold
Lymphoid nodules on pharyngeal part of the dorsum
Foramen caecum
Sulcus terminalis
Vallate papillae
Fungiform papillae

Fig. 17.1: Dorsum of the tongue, epiglottis and palatine tonsil

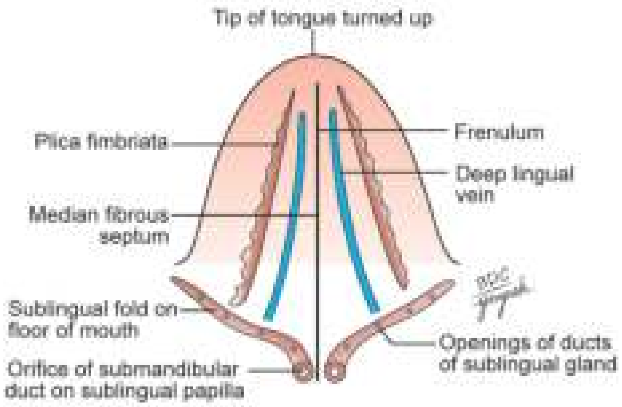

Tip of tongue turned up
Plica fimbriata
Frenulum
Deep lingual vein
Median fibrous septum
Sublingual fold on floor of mouth
Openings of ducts of sublingual gland
Orifice of submandibular duct on sublingual papilla

Fig. 17.2: Inferior surface of tongue and the floor of the mouth

Posteriormost Part

The ***posteriormost part*** *of the tongue* is connected to the epiglottis by three folds of mucous membrane. These are the median glossoepiglottic fold and the right and left lateral glossoepiglottic folds. On either side of the median fold, there is a depression called the ***vallecula*** (Fig. 17.1). The lateral folds separate the vallecula from the piriform fossa.

CLINICAL ANATOMY

- ***Glossitis*** is usually a part of generalized ulceration of the mouth cavity or stomatitis. In certain anaemias, the tongue becomes smooth due to atrophy of the filiform papillae.
- The presence of a rich network of lymphatics and of loose areolar tissue in the substance of tongue is responsible for enormous swelling of tongue in ***acute glossitis***. The tongue fills up the mouth cavity and then protrudes out of it.
- The undersurface of the tongue is a good site along with the bulbar conjunctiva for observation of ***jaundice***.
- In unconscious patients, the tongue may fall back and obstruct the air passages. This can be prevented either by lying the patient on one side with head down (the 'tonsil position') or by keeping the tongue out mechanically.
- Lingual tonsil in the posterior one-third of the tongue forms part of Waldeyer's ring.

Competency:

AN43.2 Identify, describe and draw the microanatomy of pituitary gland, thyroid, parathyroid gland, tongue, salivary glands, tonsil, epiglottis, cornea, retina.

Microanatomy of tongue is given here. For the rest of tissues, please see the appropriate chapters.

PAPILLAE OF THE TONGUE

These are projections of mucous membrane or corium which give roughness the anterior two-thirds of the tongue. These are of the following four types (Fig. 17.3 and Flowchart 17.1).

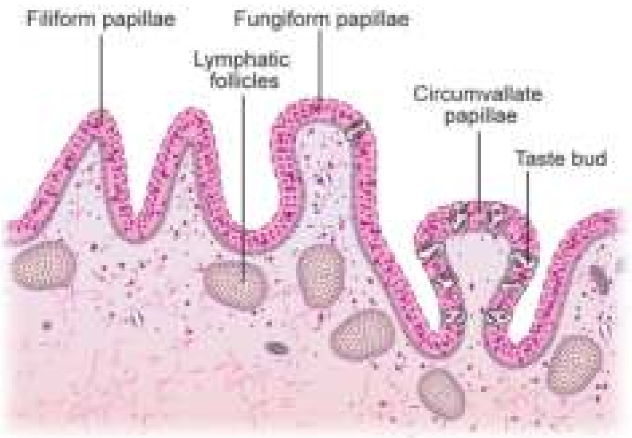
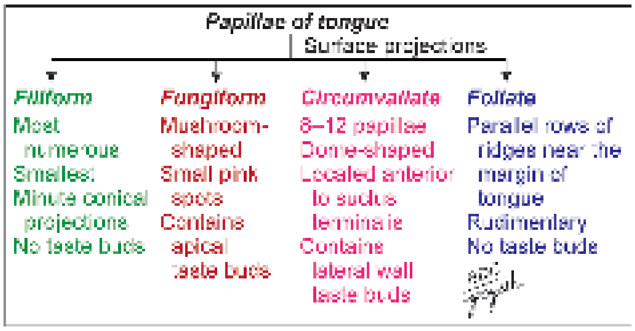

Filiform papillae
Fungiform papillae
Lymphatic follicles
Circumvallate papillae
Taste bud

Fig. 17.3: Types of papillae

Flowchart 17.1: Papillae of tongue


Papillae of tongue
Surface projections
Filiform
Most numerous
Smallest
Minute conical projections
No taste buds
Fungiform
Mushroom-shaped
Small pink spots
Contains apical taste buds
Circumvallate
8–12 papillae
Dome-shaped
Located anterior to sulcus terminalis
Contains lateral wall taste buds
Foliate
Parallel rows of ridges near the margin of tongue
Rudimentary
No taste buds

1. ***Vallate*** or ***circumvallate papillae****:* They are large in size, 1–2 mm in diameter and are 8–12 in number. They are situated immediately in front of the sulcus terminalis. Each papilla is a cylindrical projection surrounded by a circular sulcus. The walls of the papilla have taste buds.
2. ***Fungiform papillae*** are numerous near the tip and margins of the tongue, but some of them are also scattered over the dorsum. These are smaller than the vallate papillae but larger than the filiform papillae. Each papilla consists of a narrow pedicle and a large rounded head. They are distinguished by their bright red colour.
3. ***Filiform papillae*** or *conical papillae* cover the presulcal area of the dorsum of the tongue, and give it a characteristic velvety appearance. They are the smallest and most numerous of the lingual papillae. Each is pointed and covered with keratin; the apex is often split into filamentous processes.
4. ***Foliate papillae*** are present at the lateral border just in front of circumvallate papillae. They are leaf shaped.

DISSECTION

In the sagittal section, identify fan-shaped genioglossus muscle. Cut the attachments of buccinator, superior constrictor muscles and the intervening pterygomandibular raphe and reflect these downwards exposing the lateral surface of the tongue.

Competency:
AN39.1 Describe and demonstrate the morphology, nerve supply, embryological basis of nerve supply, blood supply, lymphatic drainage and actions of extrinsic and intrinsic muscles of tongue.

MUSCLES OF THE TONGUE

A middle fibrous septum divides the tongue into right and left halves. Each half contains four intrinsic and four extrinsic muscles as follows (Flowchart 17.2):

Intrinsic muscles

1. Superior longitudinal
2. Inferior longitudinal
3. Transverse
4. Vertical

Extrinsic muscles

1. Genioglossus
2. Hyoglossus
3. Styloglossus
4. Palatoglossus.

Intrinsic Muscles

They occupy the upper part of the tongue, and are attached to the submucous fibrous layer and to the median fibrous septum. They alter the shape of the tongue (Fig. 17.4, Table 17.1).

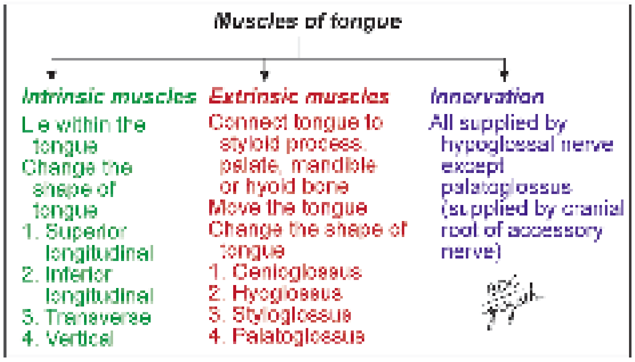
***Superior longitudinal*:** It arises from the fibrous tissue deep to the mucous membrane on the dorsum of the tongue and the midline lingual septum. It passes longitudinally back from the tip of the tongue to its root posteriorly. It inserts into the overlying mucous membrane. The superior longitudinal muscles act to elevate the tip and sides of the tongue superiorly. This shapes the dorsum of tongue into a concavity and it shortens the tongue.

***Inferior longitudinal*:** It originates from the fibrous tissue beneath the mucous membrane stretching from tip of tongue longitudinally back to the root of the tongue and the hyoid bone. It is inserted into the mucous membrane of the dorsum of tongue. It lies between the genioglossus and the hyoglossus. The inferior longitudinal muscles act to curl the tip of the tongue inferiorly. This makes the dorsum of the tongue convex in shape and shortens the tongue.

TABLE 17.1: The actions of intrinsic muscles of tongue

Intrinsic muscles	***Actions***
Superior longitudinal	Shortens the tongue, makes its dorsum concave
Inferior longitudinal	Shortens the tongue, makes its dorsum convex
Transverse	Makes the tongue narrow and elongated
Vertical (Fig. 17.4)	Makes the tongue broad and flattened

Flowchart 17.2: Muscles of tongue


Muscles of tongue
Intrinsic muscles
Lie within the tongue
Change the shape of tongue
1. Superior longitudinal
2. Inferior longitudinal
3. Transverse
4. Vertical
Extrinsic muscles
Connect tongue to styloid process, palate, mandible or hyoid bone
Move the tongue
Change the shape of tongue
1. Genioglossus
2. Hyoglossus
3. Styloglossus
4. Palatoglossus
Innervation
All supplied by hypoglossal nerve except palatoglossus (supplied by cranial root of accessory nerve)

***Transverse*:** It lies as a sheet on either side of the midline in a plane that is deep to the superior longitudinal muscles but superficial to genioglossus.

Each runs transversely from its origin at the fibrous lingual septum to insert into the submucous fibrous tissue at the lateral margins of the tongue.

Contraction of the transverse muscles acts to narrow and increases the thickness of the tongue.

***Vertical*:** It is found at the borders of the anterior part of the tongue. It makes the tongue broad.

Extrinsic Muscles

These include genioglossus, hyoglossus, styloglossus, and palatoglossus (Plate 17.1, Figs 17.5 and 17.6 and Table 17.2).

The *extrinsic muscles* connect the tongue to the mandible via genioglossus; to the hyoid bone through

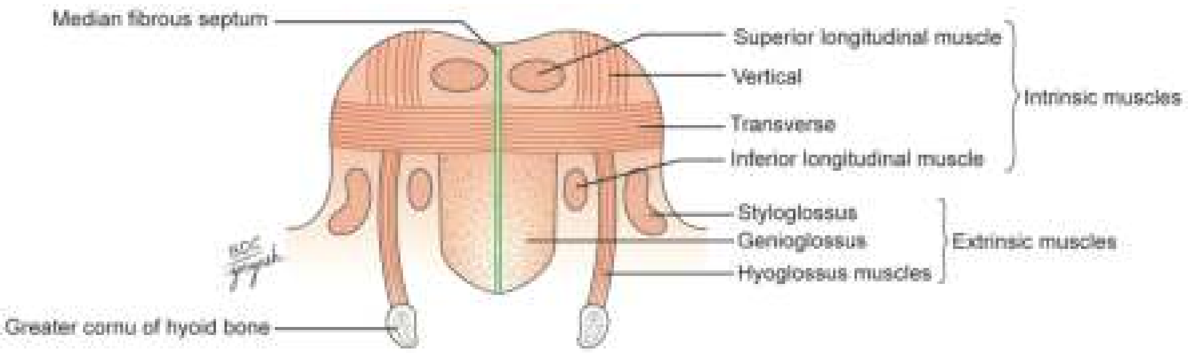
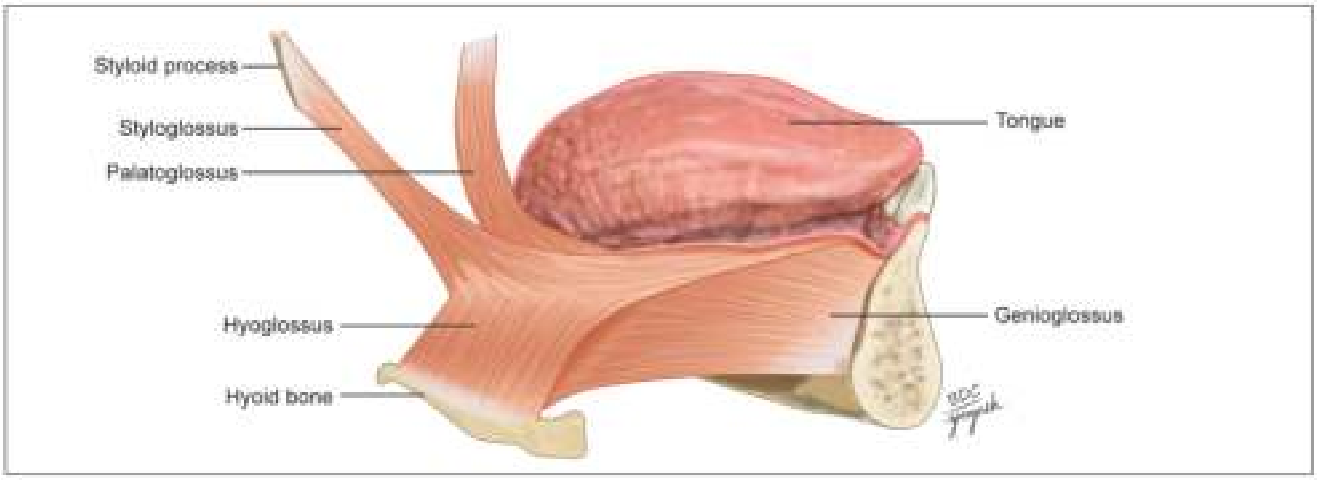

Median fibrous septum
Superior longitudinal muscle
Vertical
Transverse
Inferior longitudinal muscle
Intrinsic muscles
Styloglossus
Genioglossus
Hyoglossus muscles
Extrinsic muscles
Greater cornu of hyoid bone

Fig. 17.4: Coronal section of the tongue showing arrangement of the intrinsic and extrinsic muscles

Plate 17.1: Extrinsic muscles of the tongue (cut section, right lateral view showing muscles of right side)


Styloid process
Styloglossus
Palatoglossus
Hyoglossus
Hyoid bone
Tongue
Genioglossus

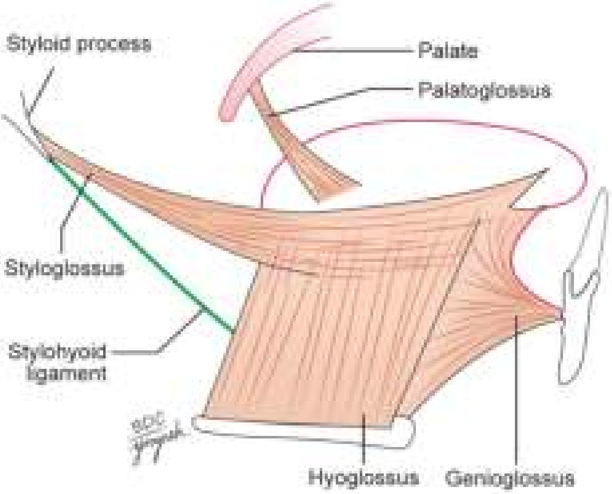

Styloid process
Palate
Palatoglossus
Styloglossus
Stylohyoid ligament
Hyoglossus
Genioglossus

Fig. 17.5: Extrinsic muscles of the tongue

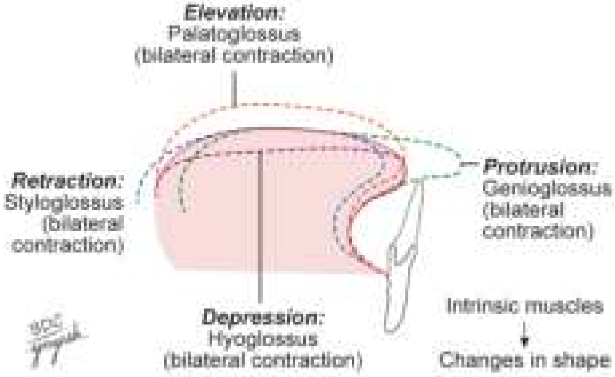

Elevation:
Palatoglossus
(bilateral contraction)
Retraction:
Styloglossus
(bilateral contraction)
Protrusion:
Genioglossus
(bilateral contraction)
Depression:
Hyoglossus
(bilateral contraction)
Intrinsic muscles
Changes in shape

Fig. 17.6: Movements of tongue

hyoglossus; to the styloid process via styloglossus, and the palate via palatoglossus.

Arterial Supply

It is derived from the tortuous ***lingual artery***, a branch of the external carotid artery. The root of the tongue is also supplied by the tonsillar artery, a branch of facial artery, and ascending pharyngeal branch of external carotid artery (Fig. 17.7).

Venous Drainage

1. *Deep lingual vein:* The chief vein of tongue, seen on the inferior surface of tongue near median plane.
2. *Venae comitantes*, accompany lingual artery. They are joined by dorsal lingual veins.
3. *Venae comitantes* accompanying the hypoglossal nerve.

These veins unite at the posterior border of the hyoglossus to form the ***lingual vein*** which ends in the internal jugular vein.

Lymphatic Drainage

The lymphatic drainage of tongue can be divided into three main regions: Marginal, central, and dorsal (*Reference*: Grey's Anatomy, 42nd edn.) (Figs 17.8a and b and Flowchart 17.3).

1. *Marginal vessels* drain the marginal area of anterior part of the tongue.
   a. The lymphatics from the tip of the tongue and lingual frenulum drains bilaterally into:
      - Submental nodes
      - Submandibular nodes
      - Jugulo-omohyoid nodes.
   b. The lymphatics from the rest of margin of the tongue drain into:
      - Submandibular nodes
      - Digastric nodes.
2. *Central vessels* drain the central region of the anterior two-thirds of tongue. They drain into jugulodigastric and jugulo-omohyoid nodes and submandibular nodes.
3. *Dorsal vessels* drain the circumvallate papillae and posterior one-third of tongue into jugulo-omohyoid and jugulodigastric nodes.

Note: The lymphatics near the median plane pass bilaterally.

The most of the lymph from the tongue finally drains to the ***jugulo-omohyoid nodes***. These are known as the ***lymph nodes of the tongue***.

Nerve Supply

Motor Nerves

All the muscles of tongue (intrinsic and extrinsic) are supplied by *hypoglossal nerve* except palatoglossus

TABLE 17.2: Origin, insertion and actions of extrinsic muscles of tongue

Muscle	*Origin*	*Insertion*	*Actions*
Palatoglossus	Oral surface of ***palatine aponeurosis***	Descends in the palatoglossal arch to the side of tongue at the junction of oral and pharyngeal parts	Pulls up the root of tongue, approximates the palatoglossal arches and thus closes the oropharyngeal isthmus
Hyoglossus	Whole length of greater cornua and lateral part of ***hyoid bone***	Side of tongue between styloglossus and inferior longitudinal muscle of tongue	Depresses tongue, makes dorsum convex, retracts the protruded tongue
Styloglossus	Tip and part of anterior surface of ***styloid process***	Into the side of tongue	Pulls tongue upwards and backwards, i.e. retracts the tongue
Genioglossus Fan-shaped bulky muscle	Upper genial tubercle of ***mandible***	*Upper fibres* into the tip of tongue *Middle fibres* into the dorsum *Lower fibres* into the hyoid bone	Retracts the tongue Depresses the tongue Pulls the posterior part of tongue forwards and protrudes the tongue. It is a ***life-saving muscle***

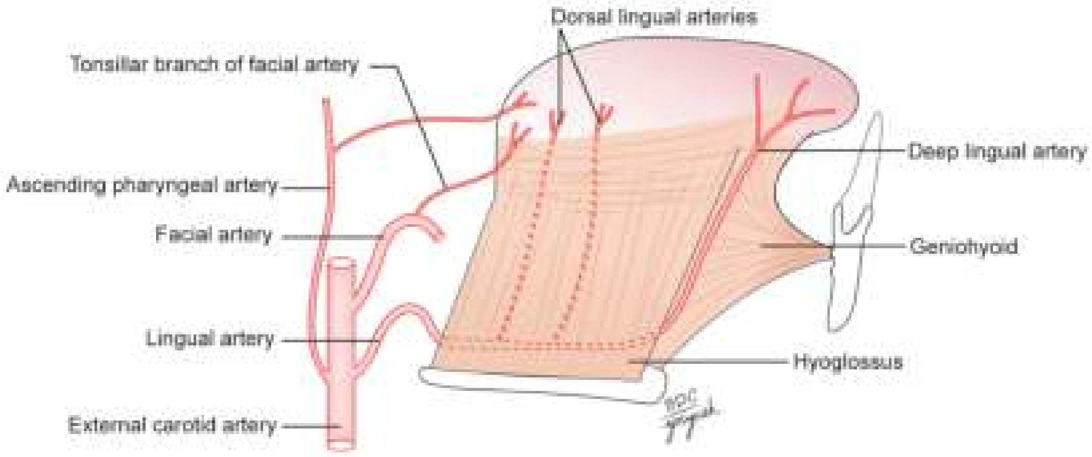
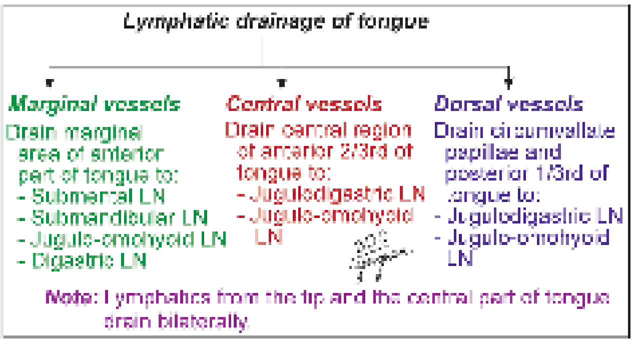


Fig. 17.7: Arterial supply and extrinsic muscles of the tongue

Flowchart 17.3: Lymphatic drainage of tongue


Lymphatic drainage of tongue

Marginal vessels
Drain marginal area of anterior part of tongue to:
- Submental LN
- Submandibular LN
- Jugulo-omohyoid LN
- Digastric LN

Central vessels
Drain central region of anterior 2/3rd of tongue to:
- Jugulodigastric LN
- Jugulo-omohyoid LN

Dorsal vessels
Drain circumvallate papillae and posterior 1/3rd of tongue to:
- Jugulodigastric LN
- Jugulo-omohyoid LN

Note: Lymphatics from the tip and the central part of tongue drain bilaterally.

which is supplied by the *cranial root of accessory nerve* via pharyngeal plexus (Fig. 17.9).

Sensory Supply

1. Anterior two-thirds of tongue without circumvallate papillae:
    - General sensations are carried by *lingual nerve*
    - Taste sensation are carried by *chorda tympani*.
2. Posterior one-third of tongue with circumvallate papillae:
   Both general and special sensation are carried by *glossopharyngeal nerve*.
3. Posterior most part is supplied by *internal laryngeal branch of superior laryngeal nerve* (branch of vagus nerve).

Note:

***Hypoglossal nerve (XII* nerve)** is the nerve of muscles of the tongue. It leaves the cranial cavity through anterior condylar/hypoglossal canal.

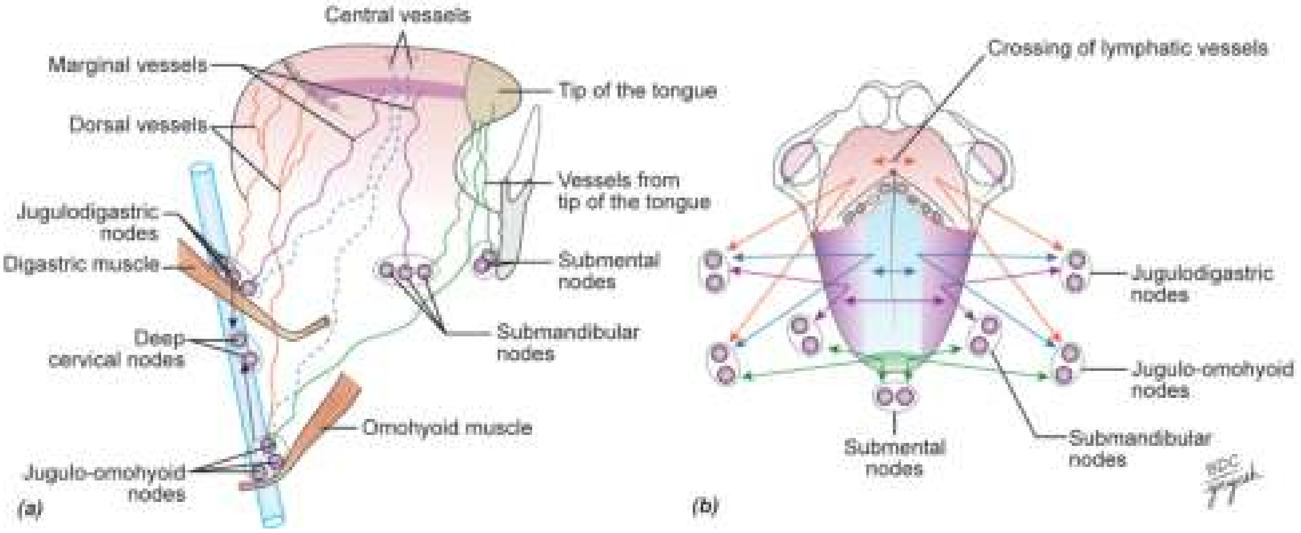
Course: Lies between internal jugular vein and internal carotid artery in front of vagus. Lower down it curves forwards to cross both internal and external carotid arteries. It also crosses loop of lingual artery to lie on hyoglossus muscle. Finally, it enters substance of tongue. It supplies 3 extrinsic muscles and all 4 intrinsic muscles of tongue (details can be read from Chapter 6, *BD Chaurasia's Human Anatomy*, *Volume 4*.

Competency:

AN39.2 Explain the anatomical basis of hypoglossal nerve palsy.

CLINICAL ANATOMY

- ***Carcinoma of the tongue*** is quite common. The affected side of the tongue is removed surgically. All the deep cervical lymph nodes are also removed, i.e. block dissection of neck because recurrence of malignant disease occurs in lymph nodes.


Central vessels
Marginal vessels
Dorsal vessels
Tip of the tongue
Vessels from tip of the tongue
Jugulodigastric nodes
Digastric muscle
Submental nodes
Submandibular nodes
Deep cervical nodes
Omohyoid muscle
Jugulo-omohyoid nodes
(a)
Crossing of lymphatic vessels
Jugulodigastric nodes
Jugulo-omohyoid nodes
Submental nodes
Submandibular nodes
(b)

Figs 17.8a and b: Lymphatic drainage of the tongue: (a) Side view and (b) superior view showing midline crossing of lymphatic vessels

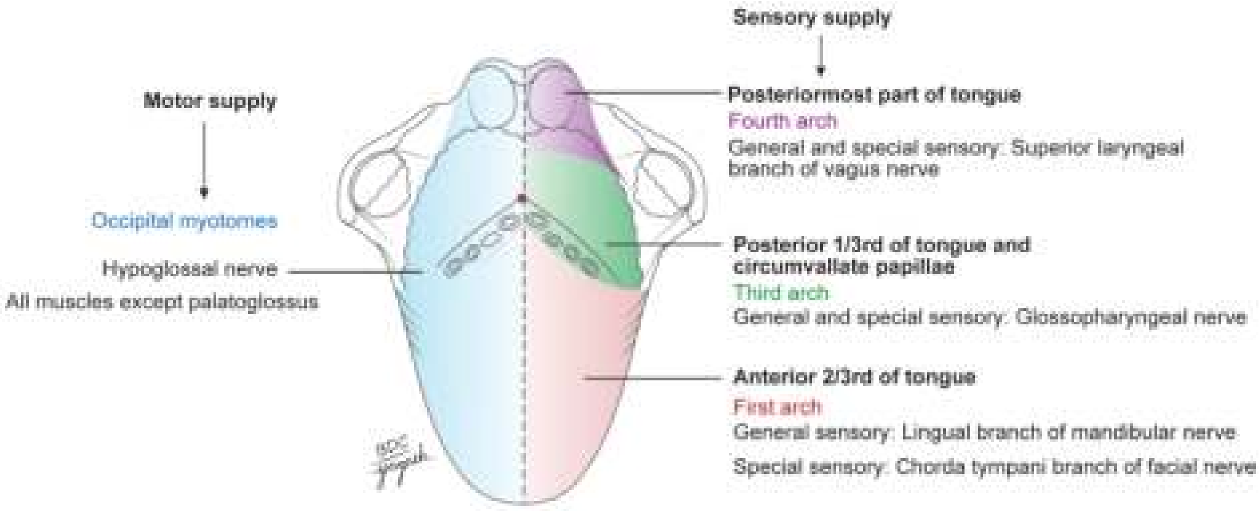

Sensory supply
Motor supply
Posteriormost part of tongue
Fourth arch
General and special sensory: Superior laryngeal branch of vagus nerve
Occipital myotomes
Hypoglossal nerve
All muscles except palatoglossus
Posterior 1/3rd of tongue and circumvallate papillae
Third arch
General and special sensory: Glossopharyngeal nerve
Anterior 2/3rd of tongue
First arch
General sensory: Lingual branch of mandibular nerve
Special sensory: Chorda tympani branch of facial nerve

Fig. 17.9: Nerve supply of tongue

- ***Sorbitrate*** is taken sublingually for immediate relief from angina pectoris. It is absorbed fast because of rich blood supply of the tongue and bypassing of portal circulation.
- Genioglossus is called the '***safety muscle of the tongue***' because if it is paralysed, the tongue will fall back on the oropharynx and block the air passage. During anaesthesia, the tongue is pulled forwards to clear the air passage.
- Genioglossus is the only muscle of the tongue that protrudes it forwards. It is used for testing the integrity of hypoglossal nerve. If hypoglossal nerve of right side is paralysed, the tongue on protrusion will deviate to the right side. Normal left genioglossus will pull the base to left side and apex will get pushed to right side (apex and base lie at opposite ends) (Fig. 17.10).

Note: The lymphatic crossing is more profound in the posterior one-third of tongue; hence, cancer in the posterior one-third of tongue has poor prognosis.

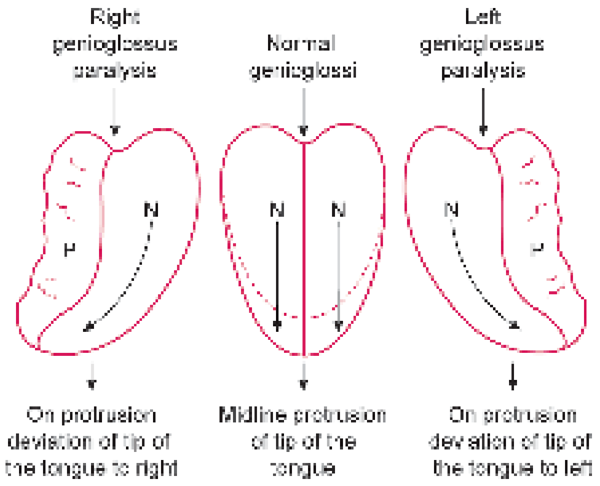

Right genioglossus paralysis
Normal genioglossi
Left genioglossus paralysis
P
N
N
N
N
P
On protrusion deviation of tip of the tongue to right
Midline protrusion of tip of the tongue
On protrusion deviation of tip of the tongue to left

Fig. 17.10: Action and unilateral paralysis of genioglossus muscle (*Note*: The tip of the tongue deviates to the paralysed side due to unopposed action of contralateral genioglossus, N: normal genioglossus, P: Paralysed genioglossus)

HISTOLOGY

Anterior Two-thirds of Tongue

The tongue consists of mucous membrane that covers core of skeletal muscle fibres (Plate 17.2).

Mucous membrane has:

- Lining epithelium – nonkeratinized stratified squamous epithelium
- Lamina propria – loose connective tissue.

Mucosa shows projecting papillae such as:

1. Filiform: Small, conical projections with keratinized tips
2. Fungiform: Mushroom-shaped projections
3. Circumvallate: Dome-shaped papillae surrounded by circular sulcus
4. Foliate: Rudimentary papillae.

Taste buds: Fungiform and circumvallate papillae have taste buds that open as taste pores. Taste buds have receptor, supporting, and basal cells (Fig. 17.11).

Skeletal muscle fibres in tongue are arranged longitudinally, transversely, and vertically.

Tongue also shows mucous lingual salivary glands and von Ebner's serous salivary glands.

Posterior One-third of Tongue

The posterior one-third of tongue consists of mucous membrane (nonkeratinized stratified squamous epithelium and lamina propria) that covers the following structures (Plate 17.3):

1. Numerous mucous lingual salivary glands and their ducts
2. Lymphatic follicles
3. Core of skeletal muscle fibres (arranged longitudinally, transversely, and vertically).

Competency:

AN43.4 Describe the development and developmental basis of congenital anomalies of face, palate, tongue, branchial apparatus, pituitary gland, thyroid gland and eye. (Development of tongue is described here. For the development of other organs please see the appropriate chapters.)

DEVELOPMENT OF TONGUE

Tongue develops in the floor of primitive pharynx and developing mouth (Fig. 17.12 and Flowchart 17.4).

Mucous Membrane

Mandibular arches show three swellings: Single midline swelling as tuberculum impar and two lateral lingual swellings. In the 4th week, two lingual swellings and tuberculum impar become visible. Caudal to tuberculum impar, proliferating epithelium forms thyroglossal duct and its pharyngeal site is marked by a depression called *foramen caecum*.

The ***lingual swellings*** grow and fuse with each other and with ***tuberculum impar***. These combined swellings form anterior two-thirds of the tongue. The developing alveololingual sulcus gradually separates tongue from floor of mouth.

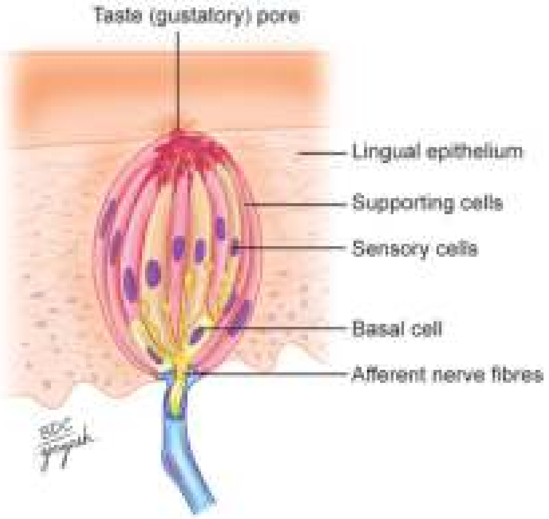

Taste (gustatory) pore
Lingual epithelium
Supporting cells
Sensory cells
Basal cell
Afferent nerve fibres

Fig. 17.11: Structure of taste bud

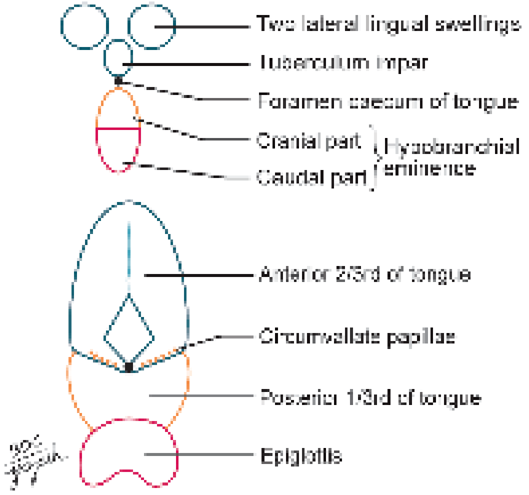
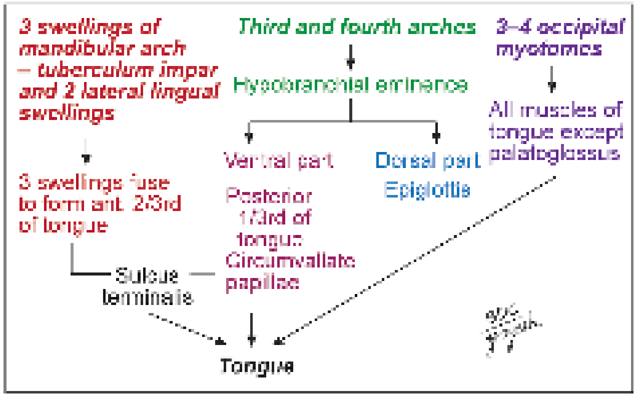

Two lateral lingual swellings
Tuberculum impar
Foramen caecum of tongue
Cranial part
Caudal part
Hypobranchial eminence
Anterior 2/3rd of tongue
Circumvallate papillae
Posterior 1/3rd of tongue
Epiglottis

Fig. 17.12: Development of tongue

Flowchart 17.4: Development of tongue


3 swellings of mandibular arch – tuberculum impar and 2 lateral lingual swellings
3 swellings fuse to form ant. 2/3rd of tongue
Sulcus terminalis
Third and fourth arches
Hypobranchial eminence
Ventral part
Posterior 1/3rd of tongue
Circumvallate papillae
Dorsal part
Epiglottis
3–4 occipital myotomes
All muscles of tongue except palatoglossus
Tongue

In relation to 3rd and 4th arches, pharyngeal surface shows a midline swelling called ***hypobranchial eminence*** or copula of His. In 5th week, hypobranchial eminence becomes visible. The hypobranchial eminence is divided into ventral and dorsal parts. Ventral part expands to form posterior one-third of the tongue. Fusion of anterior and posterior part is represented by sulcus terminalis. Caudal part of the hypobranchial eminence forms

Plate 17.2: Histology of anterior two-thirds of the tongue

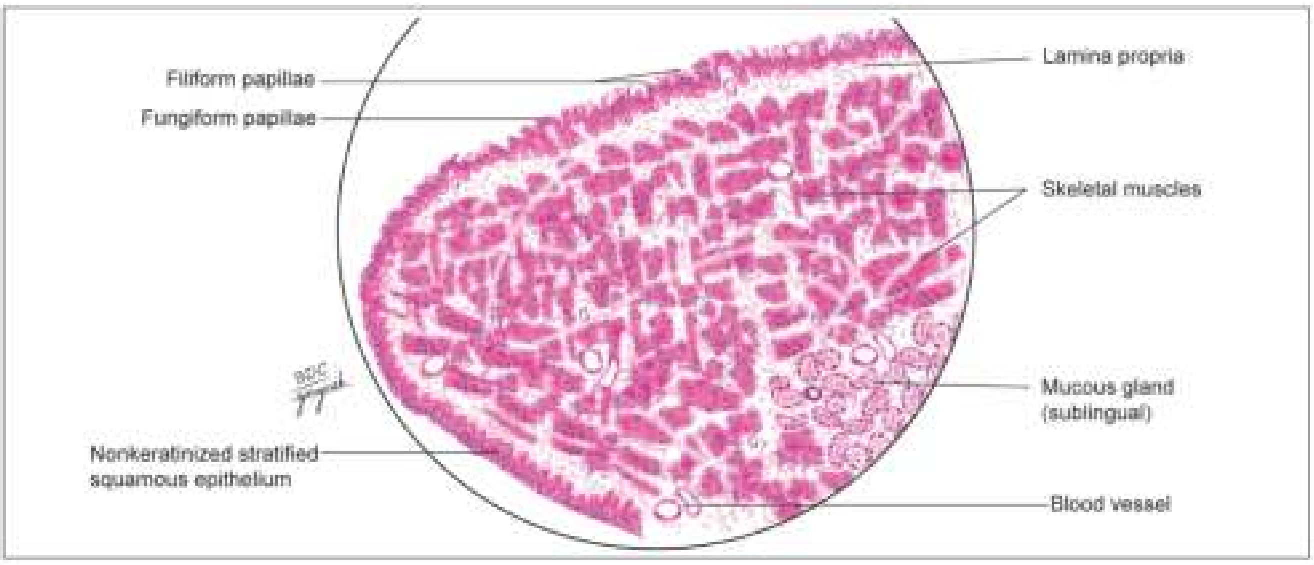
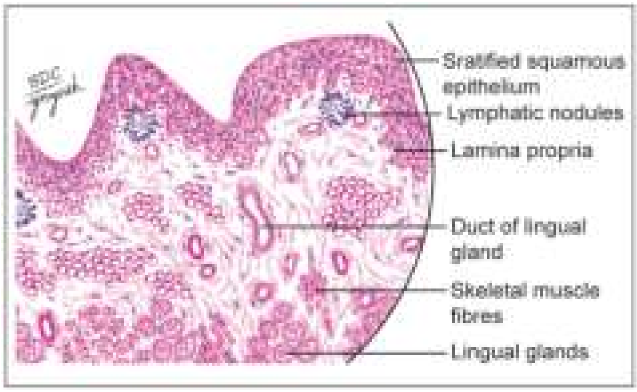

Filiform papillae
Fungiform papillae
Nonkeratinized stratified squamous epithelium
Lamina propria
Skeletal muscles
Mucous gland (sublingual)
Blood vessel

Plate 17.3: Histology of posterior one-third of tongue


Sratified squamous epithelium
Lymphatic nodules
Lamina propria
Duct of lingual gland
Skeletal muscle fibres
Lingual glands

(*Note*: Lingula tonsils are not shown in this figure to avoid the confusion with the histology of palatine tonsil)

epiglottis. Some cells migrate from posterior one-third of tongue and cross sulcus terminalis to form *circumvallate papillae*.

The 3rd arch overgrows over the second arch and fuses with the first arch; thus the 2nd arch mesoderm gets buried in the substance of the tongue.

Muscles of Tongue

About 3–4 occipital myotomes migrate ventrally to the mesenchyme of the tongue and form all extrinsic and intrinsic muscles of tongue. The occipital myotomes pull their nerve (hypoglossal nerve) during migration; hence, hypoglossal nerve crosses both external and internal carotid arteries, superficially.

Table 17.3 has the comparison of parts of the tongue.

TASTE PATHWAY

- The taste from anterior 2/3rd of tongue, except from vallate papillae, is carried by *chorda tympani* branch of facial nerve till the geniculate ganglion. The central processes go to the *tractus solitarius* in the medulla.
- Taste from posterior 1/3rd of tongue including the circumvallate papillae is carried by cranial nerve IX till the inferior ganglion. The central processes also reach the *tractus solitarius* (Fig. 17.13).
- Taste from posteriormost part of tongue and epiglottis travels through *vagus* nerve till the inferior ganglion of vagus. These *central* processes also reach *tractus solitarius*.

TABLE 17.3: Comparison of the parts of the tongue

	Anterior two-thirds	*Posterior one-third*	*Posteriormost part and vallecula*
Situation	Lies in mouth cavity	Oropharynx	Oropharynx
Structure	Contains papillae	Contains lymphoid tissue	—
Function	Chewing	Deglutition	Deglutition
Sensory nerve	Lingual (post-trematic branch of 1st arch)	Glossopharyngeal nerve of 3rd arch	Internal laryngeal branch of vagus (nerve of 4th arch)
Sensation of taste	Chorda tympani except circumvallate papillae (pre-trematic branch of 2nd arch)	Glossopharyngeal including the vallate papillae	Internal laryngeal branch of vagus
Development of epithelium from endoderm	Lingual swellings of 1st arch Tuberculum impar which soon disappears	Third arch which forms large ventral part of hypobranchial eminence	Fourth arch which forms small dorsal part of hypobranchial eminence

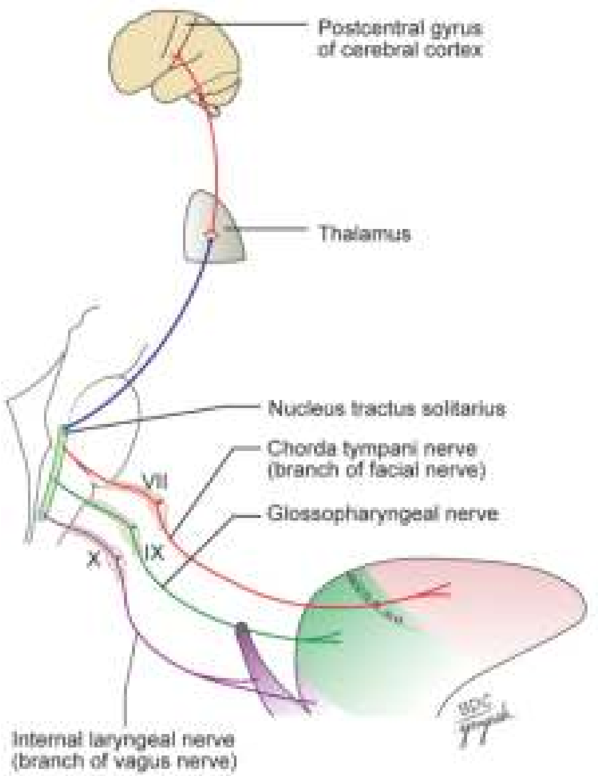

Postcentral gyrus
of cerebral cortex
Thalamus
Nucleus tractus solitarius
Chorda tympani nerve
(branch of facial nerve)
Glossopharyngeal nerve
VII
IX
X
Internal laryngeal nerve
(branch of vagus nerve)

Fig. 17.13: Taste pathways

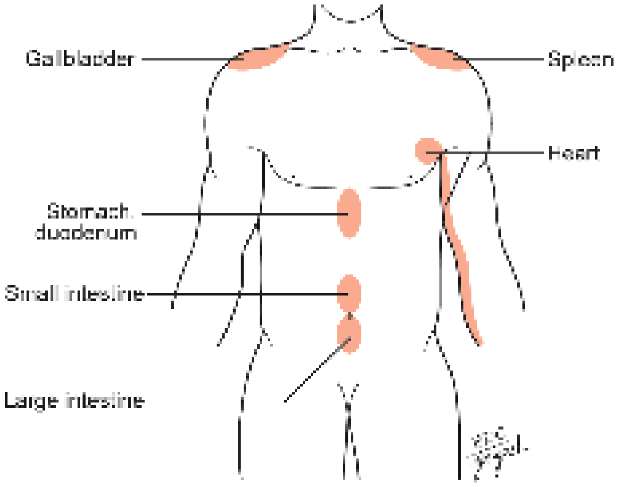

Gallbladder
Spleen
Heart
Stomach
duodenum
Small intestine
Large intestine

Fig. 17.14: Examples of referred pain

- After a relay in tractus solitarius, the *solitariothalamic tract* is formed which becomes a part of *trigeminal lemniscus* and reaches posteroventromedial nucleus of thalamus of the opposite side. Another relay here takes them to *lowest part of postcentral gyrus*, which is the area for taste.

CLINICAL ANATOMY

- Injury to any part of the pathway causes abnormality in appreciation of taste.
- Referred pain is felt in the ear in diseases of posterior part of the tongue, as 9th and 10th nerves are common supply to both the regions. Other examples of referred pain are seen in Fig. 17.14.

VIDEO

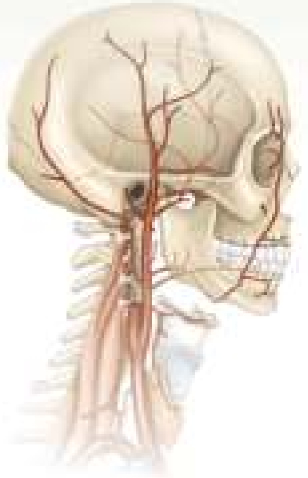
Video 3.17 Tongue

Facts to Remember

- All four intrinsic muscles of tongue are supplied by XII nerve.
- Out of four extrinsic muscles of tongue, three are supplied by XII nerve. Only palatoglossus is supplied by vagoaccessory complex.
- Lingual artery is a tortuous artery as it moves up and down with movements of pharynx.
- Tongue is kept in position by its attachment to neighbouring structures through the 4 pairs of extrinsic muscles.
- Nerve supply correlates with development. Anterior two-thirds develop from 1st arch, the nerves being lingual and chorda tympani. Chorda tympani is pretrematic branch of the 2nd arch.
- Genioglossus is the life-saving muscle as it protrudes the tongue forwards.
- Jugulo-omohyoid nodes are considered as principal lymph nodes of the tongue.

BDC's Anatomy e-book

1. Chondroglossus
2. Anatomical basis of referred pain of cancer of tongue
3. Further reading
4. Viva voce questions



Chapter

18

Ear

The ear is an organ of hearing. It is also concerned in maintaining the equilibrium of the body (Figs 18.1 and 18.2). It consists of three parts:

1. External ear
2. Middle ear
3. Internal ear.

The *tympanic membrane* separates external ear from middle ear. Mastoid antrum lies in the petrous part of temporal bone. Mastoid air cells are situated in the mastoid process.

Features of the Temporal Bone

1. *External auditory meatus* is for air waves.
2. *Internal auditory meatus* is for passage of VII, VIII nerves and labyrinthine vessels.
3. *Suprameatal triangle* is the landmark for mastoid antrum. It is bounded by supramastoid crest, posterosuperior margin of external acoustic meatus and a tangent drawn from the crest to the margin. Mastoid antrum lies about 15 mm deep to the suprameatal triangle in adult.
4. *Tympanic canaliculus* lies on the inferior surface of petrous temporal bone between carotid canal and jugular fossa.
5. *Petrotympanic fissure* gives passage to anterior tympanic artery, anterior ligament of malleus and chorda tympani nerve.
6. *Stylomastoid foramen* gives passage to stylomastoid branch for middle ear and facial nerve.
7. Hiatus for greater petrosal nerve gives passage to nerve of the same name and a branch of middle meningeal artery.
8. *Tegmen tympani* on the anterior face of petrous temporal bone forms roof of the middle ear, mastoid antrum and canal for tensor tympani muscle.
9. The aqueduct of vestibule opens on posterior aspect of petrous temporal bone. It is plugged by ductus endolymphaticus.
10. *Organ of Corti* is the end organ for hearing, situated in the cochlear duct. *Crista* is an end organ in the semicircular canal. These are kinetic balance receptors. *Macula* are end organs in the utricle and saccule and are static balance receptors.

***Competency*:**
AN40.1 Describe and identify the parts, blood supply and nerve supply of external ear.

EXTERNAL EAR

The external ear consists of:

- Auricle or pinna
- External acoustic meatus.

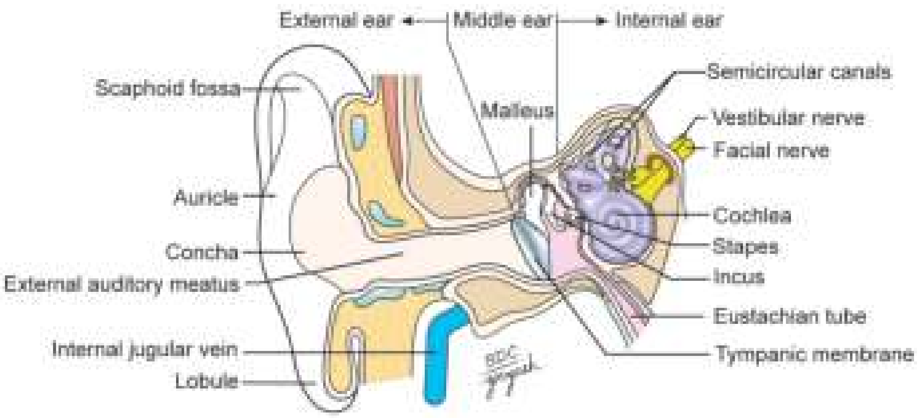

External ear
Middle ear
Internal ear
Scaphoid fossa
Semicircular canals
Malleus
Vestibular nerve
Facial nerve
Auricle
Cochlea
Concha
Stapes
External auditory meatus
Incus
Eustachian tube
Internal jugular vein
Tympanic membrane
Lobule

Fig. 18.1: The ear and its subdivisions (external, middle, and internal ear)

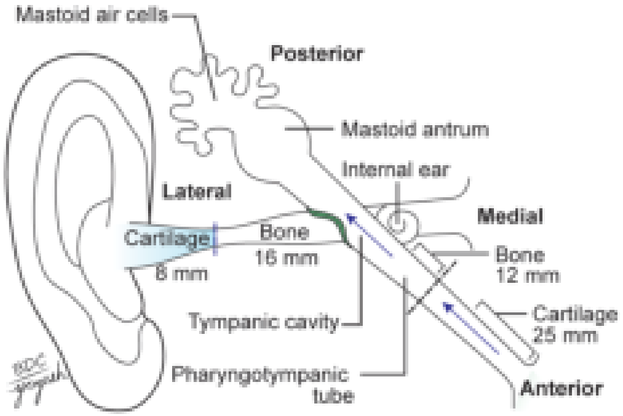

Mastoid air cells
Posterior
Mastoid antrum
Internal ear
Lateral
Medial
Cartilage
8 mm
Bone
16 mm
Bone
12 mm
Tympanic cavity
Cartilage
25 mm
Pharyngotympanic
tube
Anterior

Fig. 18.2: Parts of external ear, middle ear, and mastoid antrum (schematic representation)

AURICLE/PINNA

The auricle is the part seen on the surface.

Features

1. The greater part of it is made up of a single crumpled plate of ***elastic cartilage*** which is lined on both sides by skin. It supports the spectacles (Fig. 18.3).
2. The lowest part of the auricle is soft and consists only of fibrofatty tissue covered by skin: This part is called the ***lobule*** for wearing the ear rings.
3. The rest of the auricle is divided into a number of parts. These are helix, antihelix, concha, tragus, and scaphoid fossa. In particular, note the large depression called the ***concha***; it leads into the external acoustic meatus.
4. In relation to the auricle, there are a number of muscles. These are all vestigeal in man. In lower animals, the *intrinsic* muscles alter the shape of the auricle, while the *extrinsic* muscles move the auricle as a whole.

Nerve Supply

1. *Lateral surface*: The upper two-thirds of the lateral surface of the auricle are supplied by the auriculotemporal nerve; and the lower one-third by the great auricular nerve (Fig. 18.4).
2. *Medial surface:* The upper two-thirds of the medial surface are supplied by the lesser occipital nerve; and the lower one-third by the great auricular nerve.
3. The *root* of the auricle is supplied by the auricular branch of the vagus. The auricular muscles are supplied through branches of the facial nerve.

Blood Supply

The blood supply of the auricle is derived from the posterior auricular and superficial temporal arteries (Fig. 18.5). The *lymphatics* drain into the preauricular, and postauricular lymph nodes.

EXTERNAL ACOUSTIC MEATUS (EAM)

The external auditory meatus conducts sound waves from the concha to the tympanic membrane.

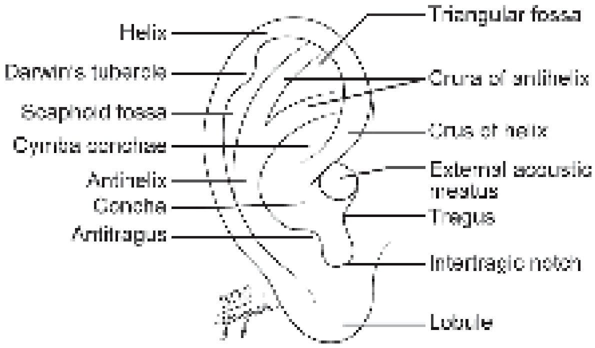
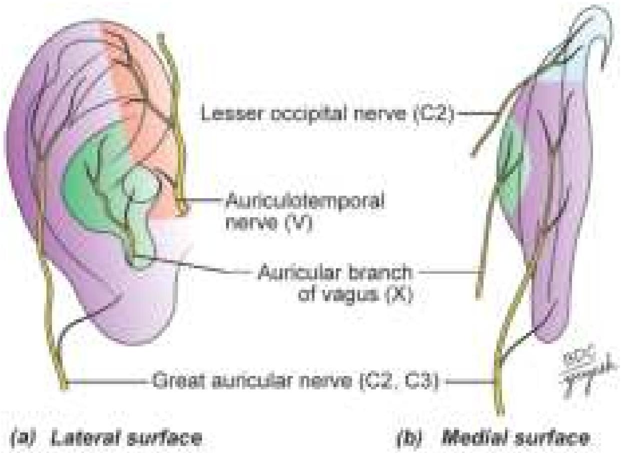

Helix
Darwin's tubercle
Scaphoid fossa
Cymba conchae
Antihelix
Concha
Antitragus
Triangular fossa
Crura of antihelix
Crus of helix
External acoustic
meatus
Tragus
Intertragic notch
Lobule

Fig. 18.3: Features of auricle


Lesser occipital nerve (C2)
Auriculotemporal
nerve (V)
Auricular branch
of vagus (X)
Great auricular nerve (C2, C3)

(a) Lateral surface *(b) Medial surface*

Figs 18.4a and b: Pinna of the ear: (a) Nerve supply of the lateral surface; (b) Nerve supply of the medial surface

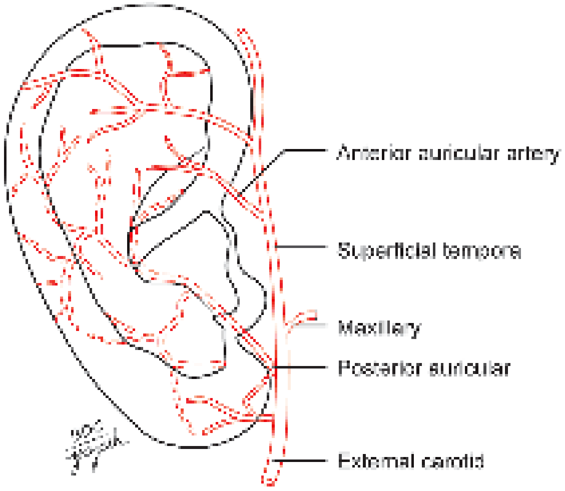

Anterior auricular artery
Superficial tempora
Maxillary
Posterior auricular
External carotid

Fig. 18.5: Blood supply of the auricle

Features

1. Its canal is S-shaped. Its outer part is directed medially, forwards and upwards. The middle part is directed medially, backwards and upwards. The inner part is directed medially, forwards and downwards.
2. The meatus can be straightened for examination by pulling the auricle *upwards, backwards and slightly laterally*.

3. The meatus or canal is about 24 mm long, of which the medial two-thirds or 16 mm is bony, and the lateral one-third or 8 mm is cartilaginous. Due to the obliquity of the tympanic membrane, the anterior wall and floor are longer than the posterior wall and roof.
4. The canal is oval in section. The greatest diameter is vertical at the lateral end, and anteroposterior at the medial end. The bony part is narrower than the cartilaginous part. The narrowest point, the *isthmus*, lies about 5 mm from the tympanic membrane.
5. The ***bony part*** is formed by the tympanic plate of the temporal bone which is C-shaped in cross-section. The posterosuperior part of the plate is deficient. Here the wall of the meatus is formed by a part of the squamous temporal bone. The meatus is lined by thin skin, firmly adherent to the periosteum.
6. The ***cartilaginous part*** is also C-shaped in section; and the gap of the 'C' is filled with fibrous tissue. The lining skin is adherent to the perichondrium, and contains hairs, sebaceous glands, and ceruminous or wax glands. *Ceruminous glands* are modified sweat glands. EAM protects tympanic membrane from blows. It maintains humidity and proper temperature.

Blood Supply

The outer part of the canal is supplied by the superficial temporal and posterior auricular arteries, and the inner part, by the deep auricular branch of the maxillary artery.

Lymphatics

The lymphatics pass to preauricular, postauricular and superficial cervical lymph nodes.

Nerve Supply

The skin lining the anterior half of the meatus is supplied by the auriculotemporal nerve, and that lining the posterior half, by the auricular branch of the vagus.

CLINICAL ANATOMY

- ***Painful boils***: The skin of the external ear is adherent to the underlying bone and cartilage. Hence, infection of hair follicles or boils in the external ear is very painful.
- ***Ear cough***: The floor and posterior wall of the external acoustic meatus is supplied by the auricular branch of vagus nerve. Irritation of this area by ear wax or cold or hot water (used in syringing) may induce ear cough, vomiting or death due to sudden cardiac arrest by vagus nerve.
- ***Alderman's nerve***: The Alderman community of ancient Rome were used to increase appetite by dropping cold water or spirit behind the ear stimulation of this area supplied by vagus nerve, in reflex, it enhances peristalsis of intestine and acid secretion in stomach.
- ***Ear wax***: Accumulation of secretions of ceruminous glands in the external ear forms ear wax. It may cause itching, irritation, and ear pain.
- ***Syringing and Waxsol eardrop***: The wax from the ear should be removed carefully using earbuds, Waxsol eardrop, or syringing (Fig. 18.6).

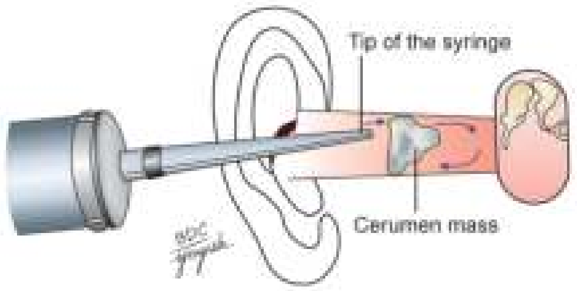


Fig. 18.6: Syringing of the ear

DISSECTION

Expose the external auditory meatus by cutting the tragus of the auricle. Put a probe into the external auditory meatus and remove the anterior wall of cartilaginous and bony parts of the external auditory meatus with the scissors. Be slow and careful not to damage the tympanic membrane.

TYMPANIC MEMBRANE

The tympanic membrane or *eardrum* is an oval semi-transparent membrane that separates the external ear from the middle ear (Figs 18.7 to 18.9 and Flowchart 18.1).

Size and Shape

- The tympanic membrane is oval.
- *Diameter*: 8 mm

Position

The tympanic membrane is placed obliquely at an angle of about 55° with the floor of external acoustic meatus. Thus, the tympanic membrane faces downward, forward, and laterally (*mnemonic*: DFL).

Tympanic membrane in newborn: The tympanic membrane in the newborn is almost horizontal.

Structure

The tympanic membrane consists of three layers:

1. Outer cuticular layer of stratified squamous epithelium (skin)
2. Middle fibrous layer
3. Inner mucosal layer of low columnar epithelium.

The inner surface of tympanic membrane provides attachment to the handle of malleus which extends up to its center. It makes the tympanic membrane convex, internally.

Umbo: It is a point of maximum convexity of the tympanic membrane. It lies at the tip of the handle of malleus.

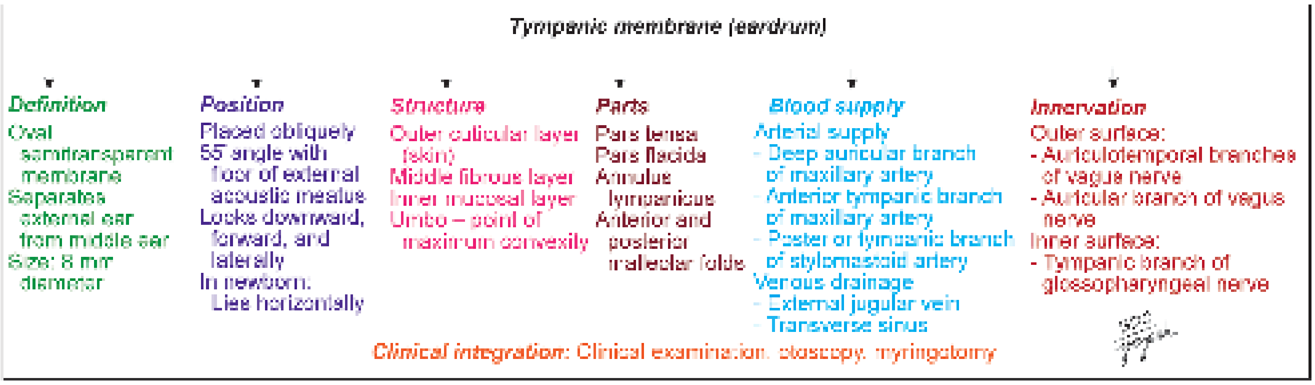
Parts

The tympanic membrane has two parts (Fig. 18.8):

1. Pars tensa
2. Pars flaccida

Pars tensa forms the greater part of the tympanic membrane. It is tightly stretched, hence called pars tensa.

Flowchart 18.1: Tympanic membrane


Tympanic membrane (eardrum)
Definition
Oval semitransparent membrane
Separates external ear from middle ear
Size: 8 mm diameter
Position
Placed obliquely 55° angle with floor of external acoustic meatus
Looks downward, forward, and laterally
In newborn: Lies horizontally
Structure
Outer cuticular layer (skin)
Middle fibrous layer
Inner mucosal layer
Umbo – point of maximum convexity
Parts
Pars tensa
Pars flaccida
Annulus tympanicus
Anterior and posterior malleolar folds
Blood supply
Arterial supply
- Deep auricular branch of maxillary artery
- Anterior tympanic branch of maxillary artery
- Posterior tympanic branch of stylomastoid artery
Venous drainage
- External jugular vein
- Transverse sinus
Innervation
Outer surface:
- Auriculotemporal branches of vagus nerve
- Auricular branch of vagus nerve
Inner surface:
- Tympanic branch of glossopharyngeal nerve
Clinical integration: Clinical examination, otoscopy, myringotomy

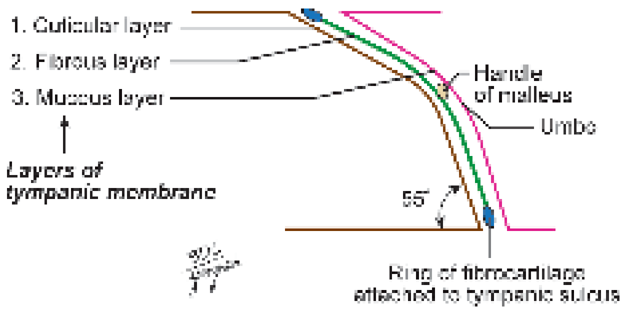

1. Cuticular layer
2. Fibrous layer
3. Mucous layer
Layers of tympanic membrane
Handle of malleus
Umbo
55°
Ring of fibrocartilage attached to tympanic sulcus

Fig. 18.7: Layers of the tympanic membrane

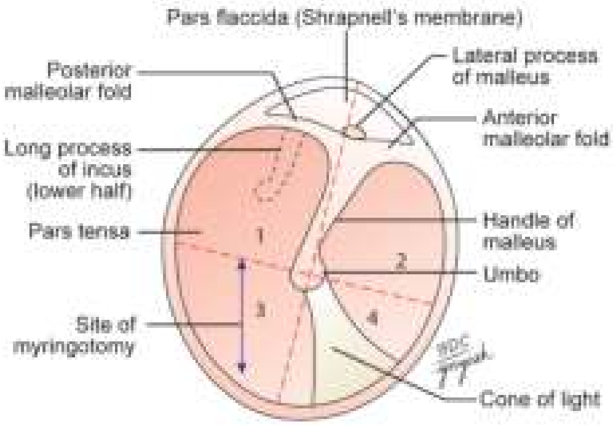

Pars flaccida (Shrapnell's membrane)
Posterior malleolar fold
Lateral process of malleus
Anterior malleolar fold
Long process of incus (lower half)
Pars tensa
Handle of malleus
Umbo
Site of myringotomy
Cone of light
1
2
3
4

Fig. 18.8: Tympanic membrane seen through the external acoustic meatus. (1) Posterosuperior quadrant; (2) Anterosuperior quadrant; (3) Posteroinferior quadrant; (4) Anteroinferior quadrant

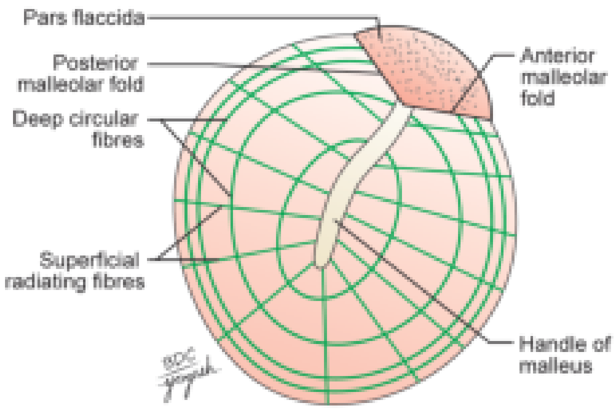

Pars flaccida
Posterior malleolar fold
Deep circular fibres
Anterior malleolar fold
Superficial radiating fibres
Handle of malleus

Fig. 18.9: Fibres of tympanic membrane

Pars flaccida (*Sharpnell's membrane*) is a small triangular area above the lateral process of malleus. It is loose, hence called pars flaccida.

Annulus tympanicus is a thick peripheral part of the tympanic membrane which fits the tympanic membrane into the tympanic sulcus.

Malleolar folds are anterior and posterior malleolar folds that run from the tympanic sulcus to the handle of malleus. They separate pars faccida from pars tensa.

Blood Supply

Arterial Supply

1. Outer surface is supplied by deep auricular branch of the maxillary artery.
2. Inner surface is supplied by:
   a. Anterior tympanic branch of maxillary artery
   b. Posterior tympanic branch of stylomastoid branch of posterior auricular artery.

Venous Drainage

1. Outer surface is drained into external jugular vein.
2. Inner surface is drained into transverse sinus and venous plexus around the auditory tube.

Lymphatic Drainage

Preauricular and retropharyngeal lymph nodes.

Innervation

1. *Outer surface*:
   Anteroinferior part – auriculotemporal branches of mandibular nerve.
   Posterosuperior part – auricular branch of vagus nerve (fibers of facial nerve).
2. *Inner surface* – tympanic branch of glossopharyngeal nerve.

Competency:
AN40.5 Explain anatomical basis of myringotomy.

CLINICAL ANATOMY

- Clinical examination of tympanic membrane: To visualize the tympanic membrane, the auricle should be pulled upward, backward, and slightly laterally in adults.

- ***Otoscope*** is useful to visualize the tympanic membrane (Fig. 18.10). It shows:
  1. Semitransparent oval tympanic membrane
  2. Concavity of the membrane directed medially
  3. *Umbo* – maximum point of concavity
  4. Handle of malleus – visualized as yellow streak extending upward and forward from umbo.
  5. Long process of incus – visualized as white prominence in the upper part of handle of malleus.
  6. Cone of light – reflected light produces cone of light in anteroinferior quadrant at 5'o clock position.
  7. Pus or blood, hole in tympanic membrane can also be visualized.
- ***Myringotomy*** is a surgical procedure to drain pus from the middle ear by giving a small incision in the tympanic membrane.

  Procedure: The incision for myringotomy is usually given in the posteroinferior quadrant of the tympanic membrane at the most bulging point and temporary ear tube is inserted. It will avoid injury to chorda tympani nerve.
- ***Injury to chorda tympani nerve*** in myringotomy: The chorda tympani nerve passes downward and forward across the inner surface of the tympanic membrane, lateral to the long process of incus and medial to the handle of malleus (Fig. 18.11). Injury to chorda tympani nerve results into:
- Loss of taste sensation over anterior two-thirds of tongue.
- Loss of salivation from submandibular and sublingual glands.

MIDDLE EAR

The middle ear is also called the tympanic cavity, or tympanum.

The middle ear is a narrow air-filled space situated in the petrous part of the temporal bone between the external ear and the internal ear (Fig. 18.12 and Flowchart 18.2).

Shape and Size

The middle ear is shaped like a cube. Its lateral and medial walls are large, but the other walls are narrow, because the cube is compressed from side-to-side.

Measurements (Fig. 18.13)

- Vertical diameter: 15 mm
- Anteroposterior diameter: 15 mm
- Transverse diameters: 6 mm at roof, 2 mm in the centre, 4 mm at the floor.

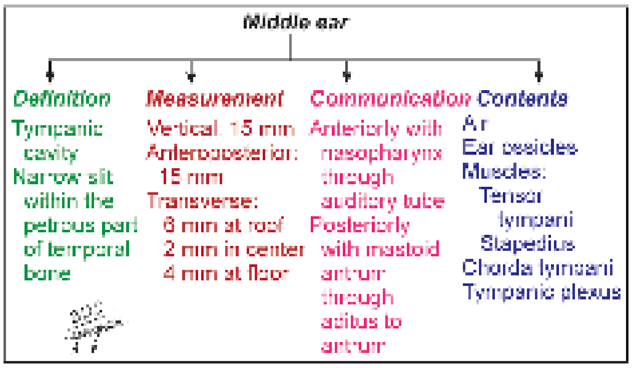
Note: The middle ear assumes full adult size at birth. On coronal section, the middle ear resembles biconcave disc (cube compressed from side-to-side).

Communications

The middle ear has two communications as follows:

1. Anterior with nasopharynx through *pharyngotympanic tube*.

Flowchart 18.2: Middle ear: Introduction


Middle ear
Definition
Tympanic cavity
Narrow slit within the petrous part of temporal bone
Measurement
Vertical: 15 mm
Anteroposterior: 15 mm
Transverse:
6 mm at roof
2 mm in center
4 mm at floor
Communication
Anteriorly with nasopharynx through auditory tube
Posteriorly with mastoid antrum through aditus to antrum
Contents
Air
Ear ossicles
Muscles:
Tensor tympani
Stapedius
Chorda tympani
Tympanic plexus

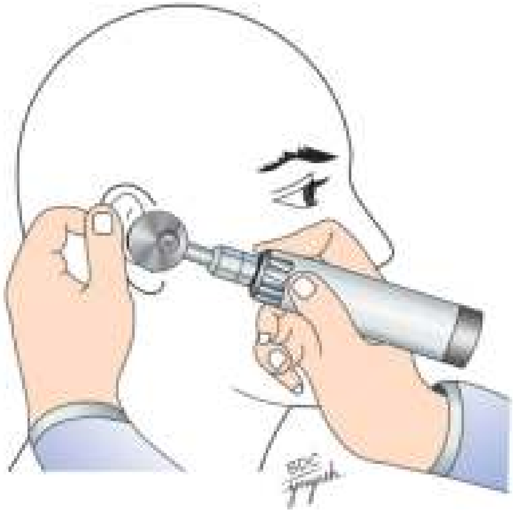


Fig. 18.10: Otoscopic examination

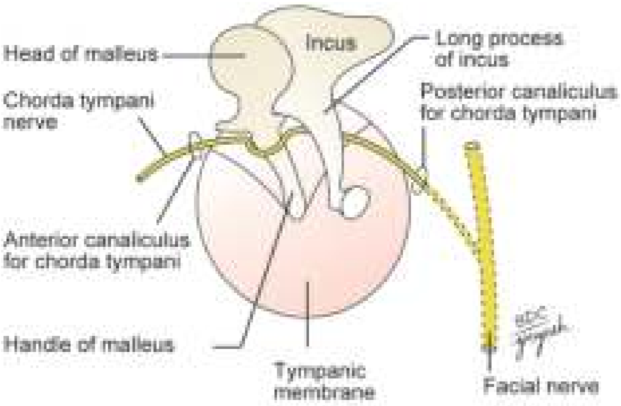

Head of malleus
Incus
Long process of incus
Chorda tympani nerve
Posterior canaliculus for chorda tympani
Anterior canaliculus for chorda tympani
Handle of malleus
Tympanic membrane
Facial nerve

Fig. 18.11: Internal surface of the right tympanic membrane

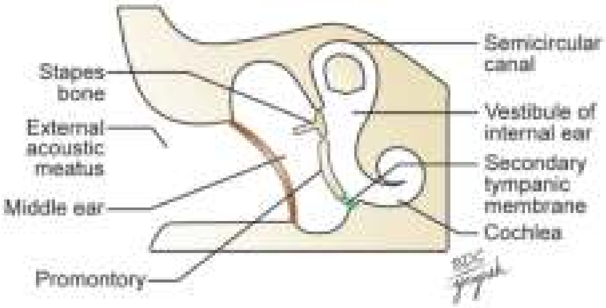

Stapes bone
External acoustic meatus
Middle ear
Promontory
Semicircular canal
Vestibule of internal ear
Secondary tympanic membrane
Cochlea

Fig. 18.12: Scheme to show the three parts of the ear

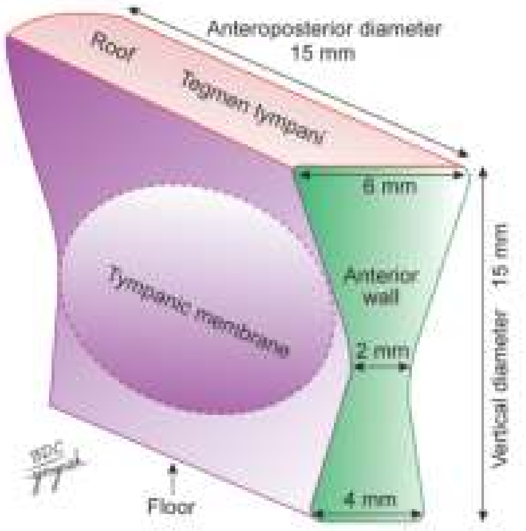

Anteroposterior diameter
15 mm
Roof
Tegmen tympani
6 mm
Anterior wall
Tympanic membrane
2 mm
Vertical diameter 15 mm
4 mm
Floor

Fig. 18.13: Measurements of middle ear

2. Posterior with mastoid antrum and mastoid air cells through *aditus to antrum*.

Contents of Middle Ear

1. Air
2. Three ear ossicles: Malleus, incus, stapes
3. Two muscles: Tensor tympani, stapedius
4. Two nerves: Chorda tympani, tympanic plexus
5. Blood vessels
6. Ligaments of ear ossicles.

Note: The mucous membrane lining the middle ear cavity invests all the contents and forms several vascular folds which project into the cavity. This gives the cavity, a honeycombed appearance.

[***Mnemonics***: ***Ear: Bones of middle ear MISs:*** **M**–Malleus, **I**–Incus, **Ss**–Stapes]

Subdivisions of Middle Ear (Fig. 18.14)

The tympanic cavity is divided into three parts as follows:

1. *Epitympanum* (*attic*) lies above the tympanic membrane.
2. *Mesotympanum* is a part that lies opposite to the tympanic membrane.
3. *Hypotympanum* lies below the tympanic membrane.

Note: The middle ear is linked to a pistol in the sloping course of the aditus to the epitympanic recess and the auditory tube (Figs 18.15a and b). The trigger of pistol is tympanic cavity. Outlet is auditory tube. Handle is aditus to mastoid antrum and mastoid air cells.

Competency:
AN40.2 Describe and demonstrate the boundaries, contents, relations and functional anatomy of middle ear and auditory tube

Boundaries

The middle ear has six walls (similar to matchbox) (Fig. 18.16 and Flowchart 18.3):

1. Roof
2. Floor
3. Lateral wall

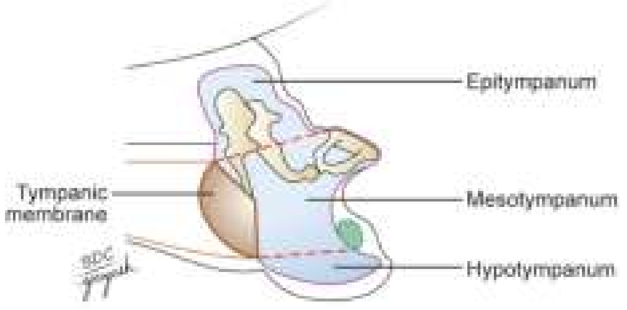
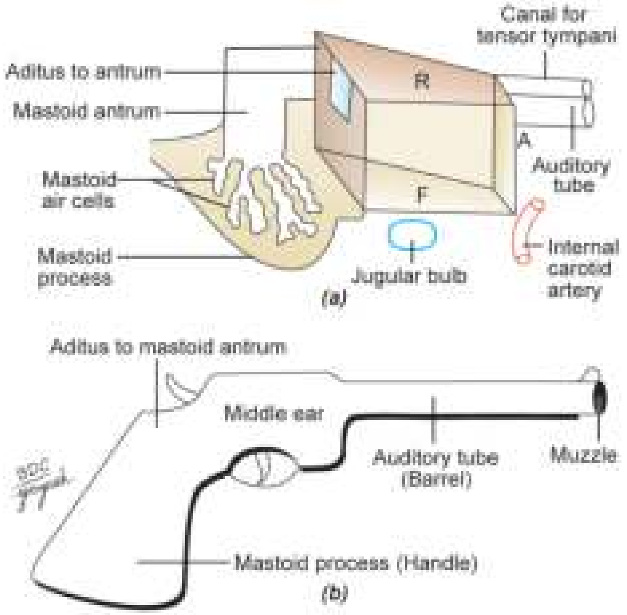

Epitympanum
Tympanic membrane
Mesotympanum
Hypotympanum

Fig. 18.14: Subdivisions of the middle ear


Canal for tensor tympani
Aditus to antrum
R
Mastoid antrum
A
Auditory tube
Mastoid air cells
F
Internal carotid artery
Mastoid process
Jugular bulb
(a)
Aditus to mastoid antrum
Middle ear
Auditory tube (Barrel)
Muzzle
Mastoid process (Handle)
(b)

Figs 18.15a and b: (a) Scheme to show some relationships of the middle ear cavity and (b) note that the cavity resembles a pistol

4. Medial wall
5. Anterior wall
6. Posterior wall.

Roof or Tegmental Wall

The roof separates the middle ear from the middle cranial fossa. It is formed by a thin plate of bone called the ***tegmen tympani***. This plate is prolonged forwards as the roof of the canal for the tensor tympani and posteriorly as the roof of the mastoid antrum (Fig. 18.16).

Note: In young children, the roof presents a gap at the unossified petrosquamous suture where the middle ear is in direct contact with the meninges. In adults, the suture is ossified and transmits a vein from the middle ear to the superior petrosal sinus.

Floor or Jugular Wall

1. The floor is formed by a thin plate of bone which separates the middle ear from the superior bulb of the internal jugular vein. This plate is a part of the temporal bone.
2. Near the medial wall, the floor presents the ***tympanic canaliculus*** which transmits the tympanic branch of the glossopharyngeal nerve to the medial wall of the middle ear.

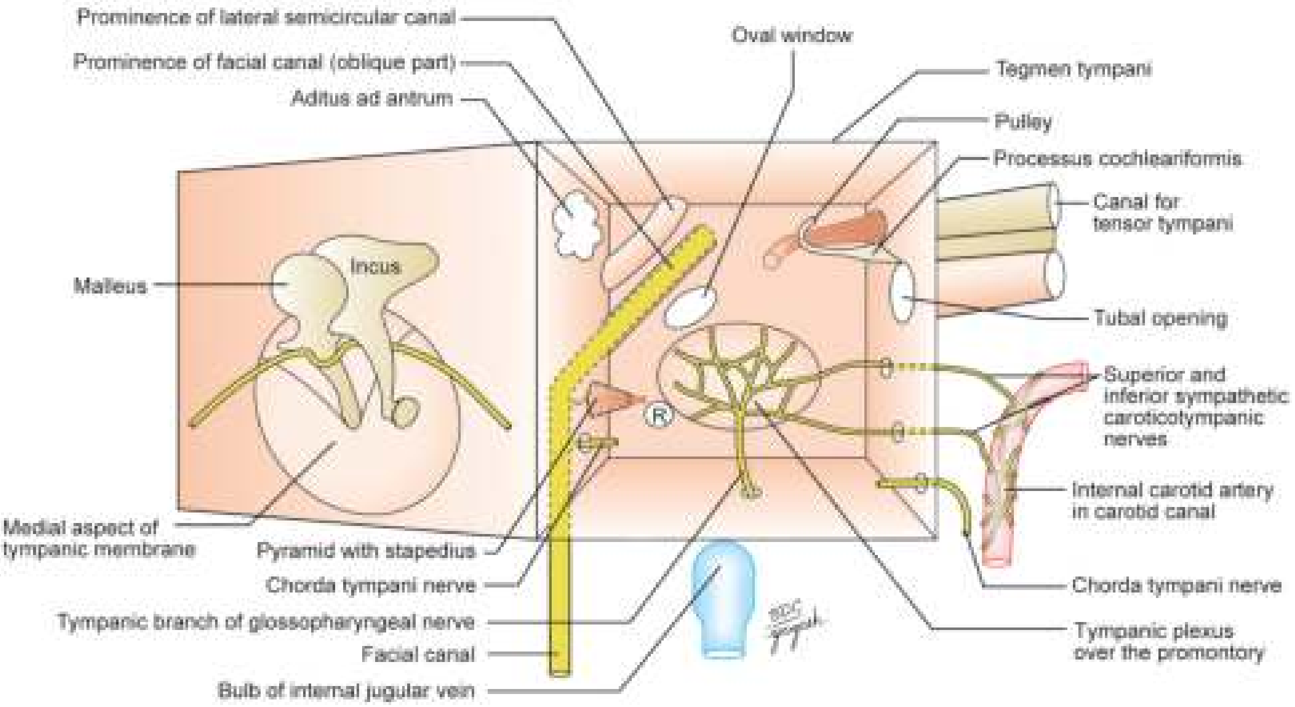
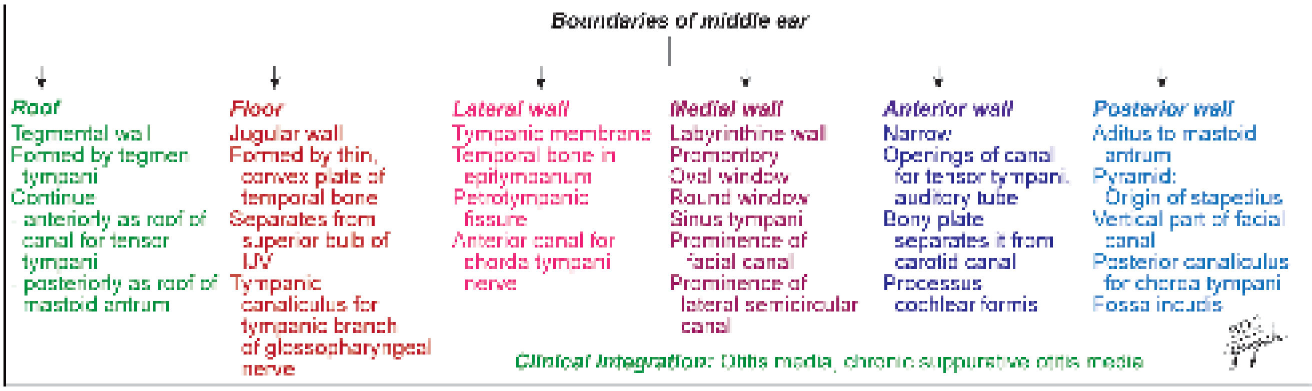

Prominence of lateral semicircular canal
Prominence of facial canal (oblique part)
Aditus ad antrum
Malleus
Incus
Medial aspect of tympanic membrane
Pyramid with stapedius
Chorda tympani nerve
Tympanic branch of glossopharyngeal nerve
Facial canal
Bulb of internal jugular vein
Oval window
R
Tegmen tympani
Pulley
Processus cochleariformis
Canal for tensor tympani
Tubal opening
Superior and inferior sympathetic caroticotympanic nerves
Internal carotid artery in carotid canal
Chorda tympani nerve
Tympanic plexus over the promontory

Fig. 18.16: Walls of middle ear (right middle ear, right lateral view, lateral wall is reflected to show interior or right middle ear, R: round window)

Flowchart 18.3: Boundaries of middle ear



Boundaries of middle ear

Roof	*Floor*	*Lateral wall*	*Medial wall*	*Anterior wall*	*Posterior wall*
Tegmental wall Formed by tegmen tympani Continue - anteriorly as roof of canal for tensor tympani - posteriorly as roof of mastoid antrum	Jugular wall Formed by thin, convex plate of temporal bone Separates from superior bulb of IJV Tympanic canaliculus for tympanic branch of glossopharyngeal nerve	Tympanic membrane Temporal bone in epitympanum Petrotympanic fissure Anterior canal for chorda tympani nerve	Labyrinthine wall Promontory Oval window Round window Sinus tympani Prominence of facial canal Prominence of lateral semicircular canal	Narrow Openings of canal for tensor tympani, auditory tube Bony plate separates it from carotid canal Processus cochlear formis	Aditus to mastoid antrum Pyramid: Origin of stapedius Vertical part of facial canal Posterior canaliculus for chorda tympani Fossa incudis

Clinical Integration: Otitis media, chronic suppurative otitis media

Lateral or Membranous Wall

1. The lateral wall separates the middle ear from the external acoustic meatus. It is formed (Fig. 18.17):
   a. Mainly by the ***tympanic membrane*** along with the tympanic ring and sulcus (described earlier).
   b. Partly by the squamous temporal bone, in the region of the epitympanic recess.
2. Near the tympanic notch, there are following small apertures:
   a. ***Petrotympanic fissure*** lies in front of the upper end of the bony rim. It lodges the anterior process of the malleus and transmits the tympanic branch of the maxillary artery.
   b. ***Anterior canaliculus for the chorda tympani*** nerve lies either in the fissure or just in front of it. The nerve leaves the middle ear through this canaliculus to emerge at the base of the skull.

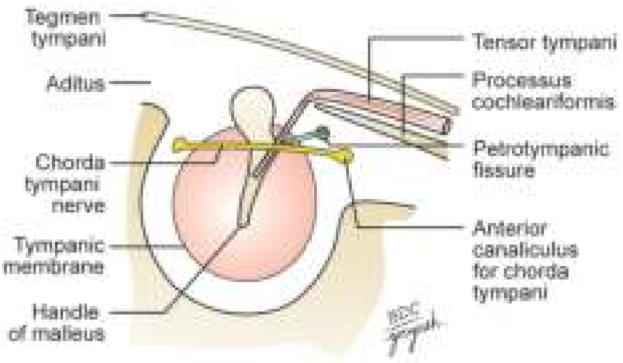

Tegmen tympani
Aditus
Chorda tympani nerve
Tympanic membrane
Handle of malleus
Tensor tympani
Processus cochleariformis
Petrotympanic fissure
Anterior canaliculus for chorda tympani

Fig. 18.17: Lateral wall of the middle ear viewed from the medial side

   c. ***Posterior canal for chorda tympani nerve*** is situated behind the tympanic membrane at the junction of the posterior and lateral walls.

Medial or Labyrinthine Wall

The medial wall separates the middle ear from the internal ear. It presents the following features:

1. ***Promontory*** is a rounded bulging produced by the first turn of the cochlea. It is grooved by the tympanic plexus (Fig. 18.18).
2. ***Fenestra vestibuli*** is an oval opening posterosuperior to the promontory. It leads into the vestibule of the internal ear and is closed by the foot-plate of the stapes.
3. ***Fenestra cochleae*** is a round opening at the bottom of a depression posteroinferior to the promontory. It opens into the scala tympani of the cochlea, and is closed by the *secondary tympanic membrane.*
4. ***Prominence of the facial canal*** runs backwards just above the fenestra vestibuli, to reach the lower margin of the aditus. The canal then descends behind the posterior wall to end at the stylomastoid foramen.
5. Prominence of lateral semicircular canal above the facial canal.
6. ***Sinus tympani*** is a depression behind the promontory, opposite the ampulla of the posterior semicircular canal.

Anterior or Carotid Wall

1. The anterior wall is narrow. It has two openings (Fig. 18.18):
   a. Opening of canal for tensor tympani above
   b. Opening of auditory tube below.
2. Below the opening of auditory tube, the anterior wall is formed by a thin plate of bone which separates the middle ear from the carotid canal and internal carotid artery. This plate is perforated by:
   a. Superior and inferior sympathetic caroticotympanic nerves and
   b. Tympanic branch of internal carotid artery.
3. ***Processus cochleariformis*** is a curved bony lamina that is extending from the bony plate separating canal for tensor tympani and auditory tube.
4. The posterior end of processus cochleariformis forms a *pulley* around which the tendon of the tensor tympani turns laterally to reach the upper part of the handle of the malleus.

Posterior or Mastoid Wall

The posterior wall presents these features from above downwards (Fig. 18.18):

1. Superiorly, there is an opening or ***aditus*** through which the epitympanic recess communicates with the mastoid or tympanic antrum.
2. The ***fossa incudis*** is a depression which lodges the short process of the incus.
3. A conical projection, called the ***pyramid***, lies near the junction of the posterior and medial walls. It has an opening at its apex for passage of the tendon of the stapedius muscle.
4. Lateral to pyramid and near the posterior edge of the tympanic membrane, is the ***posterior canaliculus for the chorda tympani*** through which the nerve enters the middle ear cavity.

Competency:
AN40.4 Explain anatomical basis of otitis externa and otitis media.

CLINICAL ANATOMY

- ***Otitis media*** is a suppurative infection of the middle ear. It is common in infants and children due to horizontally placed auditory tubes and short external ear. The infection may reach to the middle ear from nasopharynx through auditory tube or from external ear (Fig. 18.21).
- ***Chronic suppurative otitis media*** is a persistent infection of middle ear leading to persistent perforation of tympanic membranes and hearing impairment.
- ***Myringoplasty*** is a surgical procedure in which a graft is used to support healing of tympanic membrane perforation. Temporal fascia is commonly used as a graft in myringoplasty.

Ear Ossicles (Plate 18.1, Fig. 18.19)

Malleus

The malleus (Latin *hammer*) is so-called because it resembles a hammer. It is the largest, and the most laterally placed ossicle. It has the following parts:

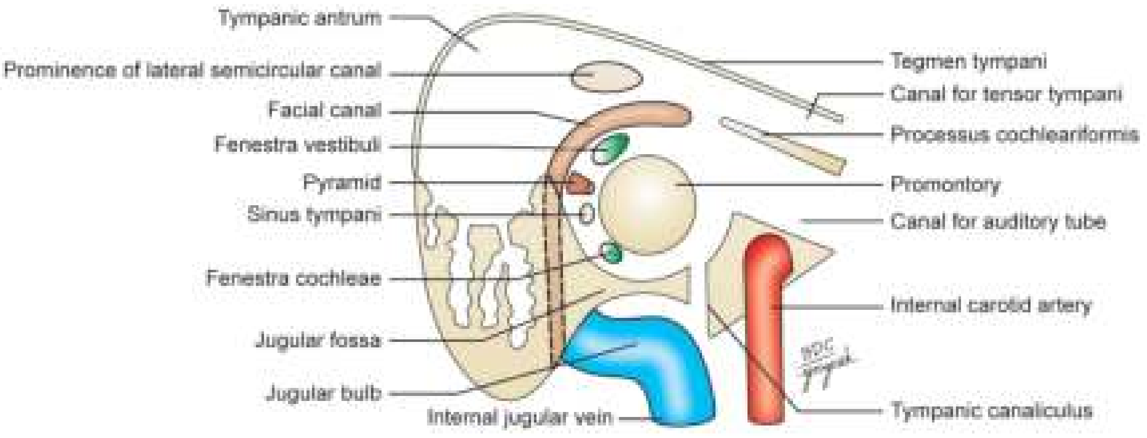
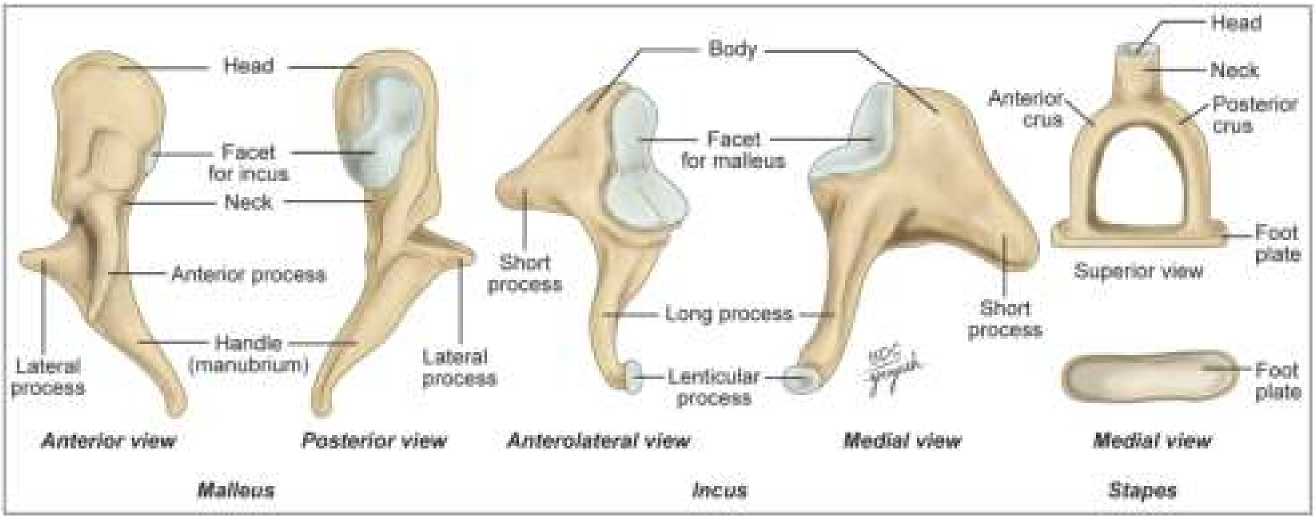


Fig. 18.18: Medial wall of the middle ear and adjacent structures

Plate 18.1: Parts of ear ossicles


Head
Facet for incus
Neck
Anterior process
Handle (manubrium)
Lateral process
Lateral process
Anterior view
Posterior view
Malleus
Body
Facet for malleus
Short process
Long process
Lenticular process
Short process
Anterolateral view
Medial view
Incus
Head
Neck
Anterior crus
Posterior crus
Foot plate
Superior view
Foot plate
Medial view
Stapes

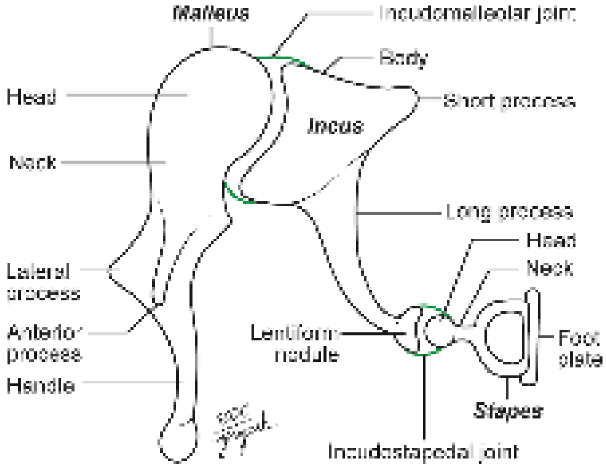

Malleus
Incudomalleolar joint
Body
Head
Short process
Incus
Neck
Long process
Head
Neck
Lateral process
Anterior process
Lentiform nodule
Foot plate
Handle
Stapes
Incudostapedial joint

Fig. 18.19: Ear ossicles

1. The rounded ***head*** lies in the epitympanic recess. It articulates posteriorly with the body of the incus. It provides attachment to the superior and lateral ligaments.
2. The *neck* lies against the pars flaccida and is related medially to the chorda tympani nerve.
3. The ***anterior process*** is connected to the petrotympanic fissure by the anterior ligament.
4. The ***lateral process*** projects from the upper end of the handle and provides attachment to the malleolar folds.
5. The ***handle*** extends downwards, backwards and medially, and is attached to the upper half of the tympanic membrane.

Incus or Anvil

It is so-called because it resembles an anvil, used by blacksmiths. It resembles a molar tooth and has the following parts:

1. The ***body*** is large and bears an articular surface that is directed forwards. It articulates with the head of the malleus.
2. The ***long process*** projects downwards just behind and parallel with the handle of the malleus. Its tip bears a lentiform nodule directed medially which articulates with the head of the stapes.

Stapes

This bone is so-called because it is shaped like a stirrup. It is the smallest, and the most medially placed ossicle of the ear.

It has the following parts:

a. The small ***head*** has a concave facet which articulates with the lentiform nodule of the incus.
b. The narrow ***neck*** provides insertion, posteriorly, to the thin tendon of the stapedius.
c. ***Two limbs*** or crura; anterior, the shorter and less curved; and posterior, the longer which diverge from the neck and are attached to the footplate.
d. The ***footplate***, a *footpiece* or *base*, is oval in shape, and fits into the fenestra vestibuli.

Joints of the Ossicles

1. The ***incudomalleolar joint*** is a saddle joint.
2. The ***incudostapedial joint*** is a ball and socket joint. Both of them are synovial joints. They are surrounded by capsular ligaments. Accessory ligaments are three for the malleus, and one each for the incus and the stapes which stabilize the ossicles. All ligaments are extremely elastic (Fig. 18.19).

Muscles of the Middle Ear

There are two muscles—the tensor tympani and the stapedius. Both act simultaneously to damp down the intensity of high-pitched sound waves and thus protect the internal ear (Table 18.1).

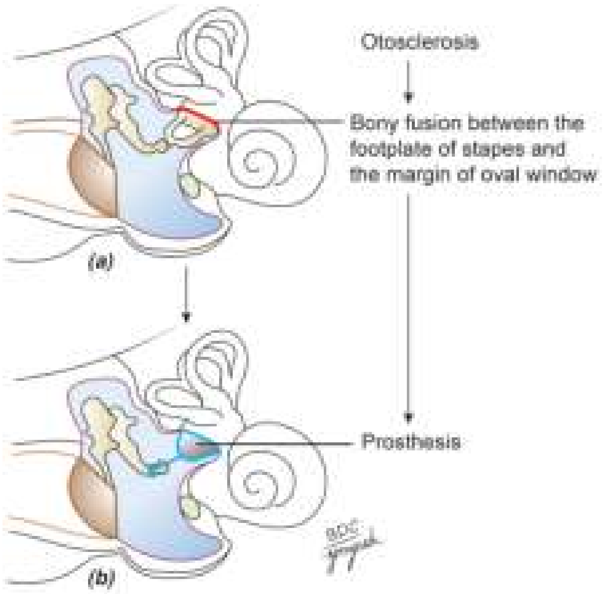
Tensor tympani is derived from the 1st branchial arch, whereas the stapedius from 2nd branchial arch.

CLINICAL ANATOMY

- ***Otosclerosis*** is a bony fusion between the footplate of stapes and the margin of oval window. It leads to deafness. The condition of deafness or otosclerosis can be treated with prosthesis (Figs 18.20a and b).

TABLE 18.1: Muscles of middle ear (intratympanic muscles)

Muscle	*Origin*	*Insertion*	*Innervation*	*Actions*
Tensor tympani Long, slender muscle lies in the bony canal	Cartilaginous part of auditory tube Greater wing of sphenoid	Tendon bends sharply around the *processus cochleariformis* to insert at the handle of malleus	Mandibular nerve (V3)	Tenses the tympanic membrane To damp sound vibrations
Stapedius	Internal walls of pyramidal eminence that lie on the posterior wall of middle ear Its tendon emerges through the tip of pyramid	Posterior aspect of neck of stapes	Facial nerve (VII)	Draw stapes laterally To damp excessive sound vibrations


Otosclerosis
Bony fusion between the footplate of stapes and the margin of oval window
(a)
Prosthesis
(b)

Figs 18.20a and b: (a) Otosclerosis and (b) treated by a prosthesis

- ***Stapedectomy*** is a surgical removal of stapes in case of otosclerosis.
- ***Stapedotomy***: Some surgeons refixed same stapes instead of its removal. This method is called stapedotomy.
- ***Hyperacusis***: Tensor tympani and stapedius dampen very loud sounds and protect the internal ear. Paralysis of these muscles result in hyperacusis.

Arterial Supply

The middle ear is supplied by six arteries:

1. Anterior tympanic branch of maxillary artery
2. Stylomastoid branch of posterior auricular artery
3. Petrosal branch of middle meningeal artery
4. Superior tympanic branch of middle meningeal artery
5. Branch from artery of pterygoid canal
6. Tympanic branch of internal carotid artery.

Note: The anterior tympanic branch of the maxillary artery which enters the middle ear through the petrotympanic fissure. The posterior tympanic branch of the stylomastoid branch of the posterior auricular artery which enters through the stylomastoid foramen.

Venous Drainage

Veins from the middle ear drain into the superior petrosal sinus and the pterygoid plexus of the veins.

Lymphatic Drainage

Lymphatics pass to the preauricular and retropharyngeal lymph nodes.

Nerve Supply

The nerve supply is derived from the tympanic plexus which lies over the promontory. The plexus is formed by the following.

1. The tympanic branch of the glossopharyngeal nerve. Its fibres are distributed to the mucous membrane of the middle ear, auditory tube, mastoid antrum and air cells. It also gives off the lesser petrosal nerve.
2. The superior and inferior caroticotympanic nerves arise from the sympathetic plexus around the internal carotid artery. These fibres are vasomotor to the mucous membrane.

CLINICAL ANATOMY

Otalgia (*ear pain*): The pain of the middle ear and external ear gets referred to:

1. Tongue tonsil and pharynx, through glossopharyngeal nerve
2. Teeth through mandibular nerve.

FUNCTIONS OF THE MIDDLE EAR

1. It transmits sound waves from the external ear to the internal ear through the chain of ear ossicles, and thus transforms the air-borne vibrations from the tympanic membrane to liquid-borne vibrations in the internal ear.
2. The intensity of the sound waves is increased ten times by the ossicles. It may be noted that the frequency of sound does not change.

DISSECTION

Remove the dura mater and endosteum from the floor of the middle cranial fossa. Identify greater petrosal nerve emerging from a canaliculus on the anterior surface of petrous temporal bone. Trace it as it passes inferior to trigeminal ganglion to reach the carotid canal.

Carefully break the roof of the middle ear formed by tegmen tympani which is a thin plate of bone situated parallel and just lateral to the greater petrosal nerve. Cavity of the middle ear can be visualised. Try to put a probe in the anteromedial part of the cavity of middle ear till it appears at the opening in the lateral wall of nasopharynx. Identify the posterior wall of the middle ear which has an opening in its upper part. This is the aditus to mastoid antrum, which in turn, connects the cavity to the mastoid air cells.

Ear ossicles

Identify the bony ossicles. Locate the tendon of tensor tympani muscle passing from the malleus towards the medial wall of the cavity where it gets continuous with the muscle. Trace the tensor tympani muscle traversing in a semicanal above the auditory tube. Break one wall of the pyramid to visualise the stapedius muscle. Just superior to the attachment of tendon of tensor tympani, look for chorda tympani traversing the tympanic membrane.

TYMPANIC OR MASTOID ANTRUM

Features

Mastoid antrum is a small, circular, air-filled space situated in the posterior part of the petrous temporal bone. It is of adult size at birth, size of a small pea, or 1 cm in diameter and has a capacity of about 1 ml (Fig. 18.21).

Boundaries

Superiorly: Tegmen tympani, and beyond it the temporal lobe of the cerebrum.

Inferiorly: Mastoid process containing the mastoid air cells.

Anteriorly: It communicates with the epitympanic recess through the aditus. The aditus is related medially to the ampullae of the superior and lateral semicircular canals, and posterosuperiorly to the facial canal.

Posteriorly: It is separated by a thin plate of bone from the sigmoid sinus. Beyond the sinus there is the cerebellum.

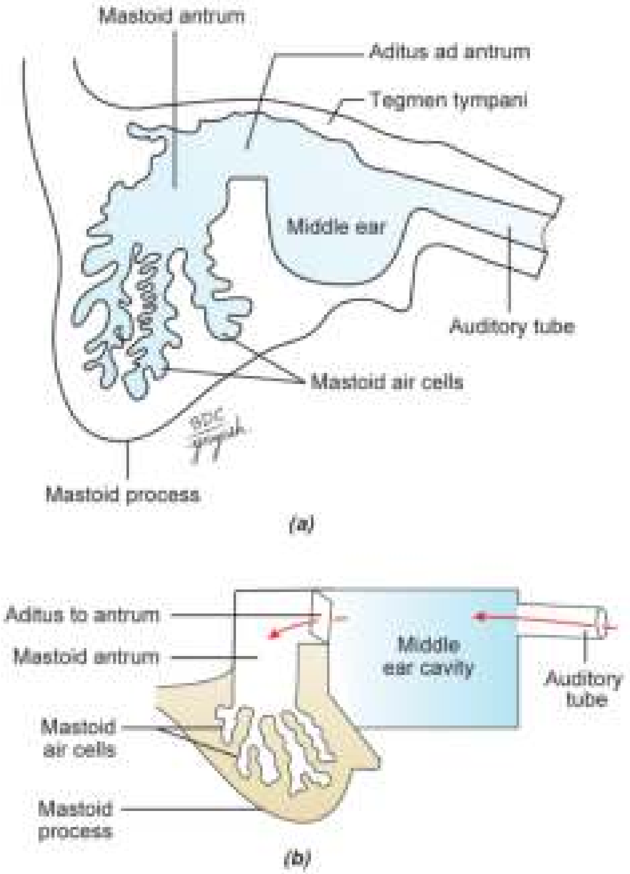
Medially: Petrous temporal bone.

Laterally: It is bounded by part of the squamous temporal bone.

Note: The lateral wall of mastoid antrum corresponds to the *suprameatal triangle* seen on the surface of the bone. This wall is 2 mm thick at birth, but increases in thickness at the rate of about 1 mm per year up to a maximum of about 12 to 15 mm.

Mastoid Air Cells

Mastoid air cells are a series of intercommunicating spaces of variable size present within the mastoid process. Their number varies considerably. Sometimes there are just a few, and are confined to the upper part of the mastoid process. Occasionally, they may extend beyond the mastoid process into the squamous or petrous parts of the temporal bone.



Figs 18.21a and b: (a) Mastoid antrum and mastoid air cells (section through long axis of the petromastoid bone) and (b) schematic representation

Vessels, Lymphatics and Nerves

The mastoid antrum and air cells are supplied by the *posterior tympanic artery* derived from the stylomastoid branch of the posterior auricular artery. The *veins* drain into the mastoid emissary vein, the posterior auricular vein and the sigmoid sinus.

Lymphatics pass to the postauricular and upper deep cervical lymph nodes.

Nerves are derived from the tympanic plexus formed by the glossopharyngeal nerve and from the meningeal branch of the mandibular nerve.

CLINICAL ANATOMY

- Fracture of the middle cranial fossa breaks the roof of the middle ear, ruptures the tympanic membrane, and thus causes bleeding through the ear along with discharge of CSF.
- Throat infections commonly spread to the middle ear through the auditory tube and cause ***otitis media***. The pus from the middle ear may erode the floor and spread downwards, causing thrombosis of the sigmoid sinus and the internal jugular vein (Fig. 18.22).
- ***Bezold's abscess*** is subperiosteal postauricular abscess. The spread of infection of mastoiditis may cause Bezold's abscess.

- Mastoiditis is a potentially dangerous and life-threatening condition as it can easily spread to cranial cavity.
- ***Dehiscence of the facial nerve canal***: Occasionally, the facial nerve may split into two-to-three strands while passing through the facial canal (Fig. 18.23).
- ***Cholesteatoma*** is an abnormal middle ear cavity lined by stratified squamous epithelium. (Normally, middle ear cavity is lined by ciliated columnar epithelium except over ear ossicles, posterior wall, posterior part of medial wall, parts of tympanic membrane, mastoid antrum, and mastoid air cells where it is lined by nonciliated flat epithelium.)
- Glands are absent in mucosa of tympanic cavity, but goblet cells are abundant.
- ***Mastoid abscess*** is secondary to otitis media.
- In surgical drainage of mastoid abscess, facial nerve should be protected carefully.

DISSECTION

Clean the mastoid temporal bone off all the muscles and identify suprameatal triangle and supramastoid crest. Use a fine chisel to remove the bone of the triangle till the mastoid antrum is reached. Examine the extent of mastoid air cells.

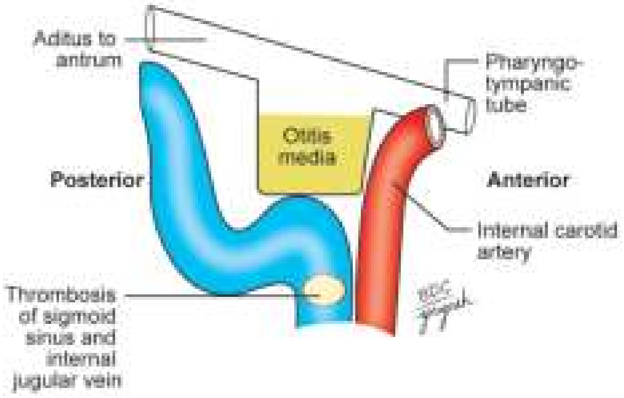


Fig. 18.22: Otitis media causing thrombosis of the sigmoid sinus and the internal jugular vein

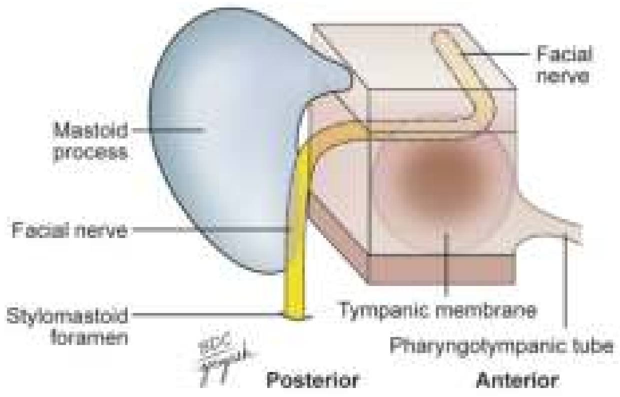


Fig. 18.23: Site of injury to facial nerve during mastoid operation

Remove the posterior and superior walls of external auditory meatus till the level of the roof of mastoid antrum. Identify the chorda tympani nerve at the posterosuperior margin of tympanic membrane.

Look for arcuate eminence on the anterior face of petrous temporal bone. Identify internal acoustic meatus on the posterior face of petrous temporal bone, with the nerves in it. Try to break off the superior part of petrous temporal bone above the internal acoustic meatus. Identify the facial nerve as it passes towards the aditus. Identify the sharp bend of the facial nerve with the geniculate ganglion.

Identify the facial nerve turning posteriorly into the medial wall. Trace it above the fenestra vestibuli till it turns inferiorly in the medial wall of aditus.

Identify facial nerve at the stylomastoid foramen. Try to break the bone vertically along the lateral edge of the foramen to expose the whole of facial nerve canal.

Break off more of the superior surface of the petrous temporal bone. Remove the bone gently. Examine the holes in the bone produced by semicircular canals and look for the semicircular ducts lying within these canals. Note the branches of vestibulocochlear nerve entering the bone at the lateral end of the meatus. Study the internal ear from the models in the museum.

Competency:
AN40.3 Describe the features of internal ear.

INTERNAL EAR

The internal ear, or labyrinth, lies in the petrous part of the temporal bone. It consists of:

1. *Bony labyrinth* within which there is a membranous labyrinth.
2. *Membranous labyrinth* is filled with a fluid called *endolymph*. It is separated from the bony labyrinth by another fluid called the *perilymph*.

BONY LABYRINTH

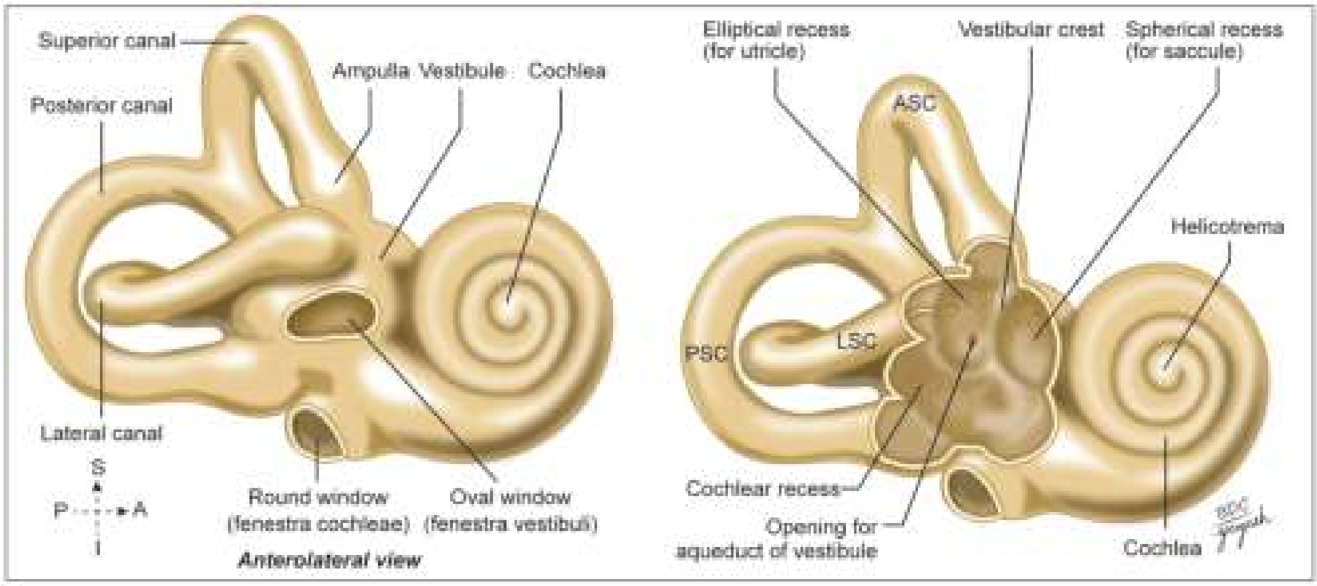
The bony labyrinth consists of three parts (Plate 18.2 and Flowchart 18.4):

1. Cochlea, anteriorly
2. Vestibule, in the middle
3. Semicircular canals, posteriorly.

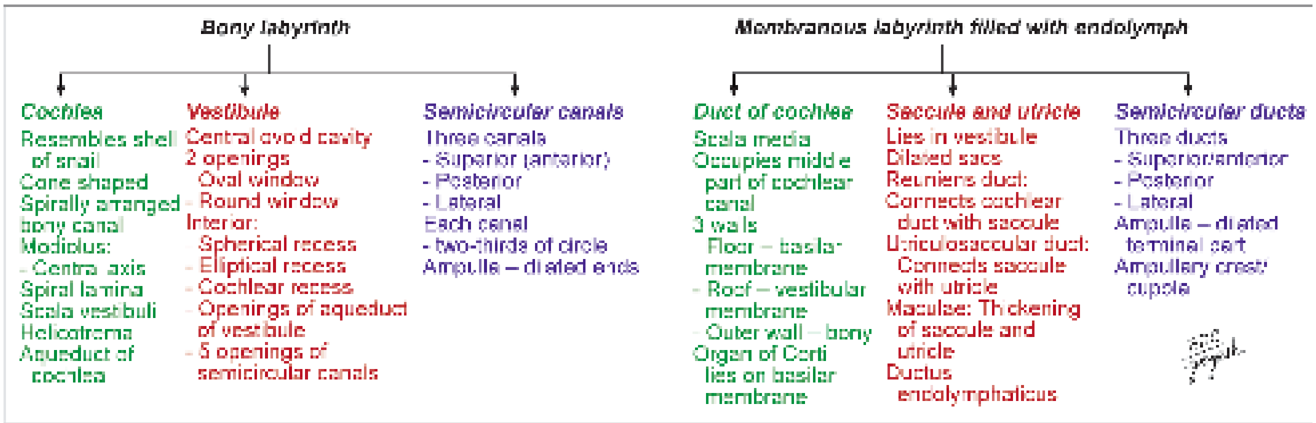
Cochlea

1. The bony cochlea resembles the shell of a common snail. It forms the anterior part of the labyrinth. It has a conical central axis known as the ***modiolus*** around which the cochlear canal makes two and three quarter turns (Fig. 18.24).
2. The modiolus is directed forwards and laterally. Its apex points towards the anterosuperior part of the medial wall of the middle ear and the base towards the fundus of the internal acoustic meatus.

Plate 18.2: Right bony labyrinth and interior of vestibule (medial view, ASC, LSC, PSC: Anterior, lateral and posterior semicircular canals)


Superior canal
Posterior canal
Ampulla
Vestibule
Cochlea
Lateral canal
S
P
A
I
Round window (fenestra cochleae)
Oval window (fenestra vestibuli)
Anterolateral view
Elliptical recess (for utricle)
Vestibular crest
Spherical recess (for saccule)
ASC
Helicotrema
PSC
LSC
Cochlear recess
Opening for aqueduct of vestibule
Cochlea

Flowchart 18.4: Bony and membranous labyrinth


Bony labyrinth
Cochlea
Resembles shell of snail
Cone shaped
Spirally arranged bony canal
Modiolus:
- Central axis
Spiral lamina
Scala vestibuli
Helicotrema
Aqueduct of cochlea
Vestibule
Central ovoid cavity
2 openings
- Oval window
- Round window
Interior:
- Spherical recess
- Elliptical recess
- Cochlear recess
- Openings of aqueduct of vestibule
- 5 openings of semicircular canals
Semicircular canals
Three canals
- Superior (anterior)
- Posterior
- Lateral
Each canal
- two-thirds of circle
Ampulla – dilated ends
Membranous labyrinth filled with endolymph
Duct of cochlea
Scala media
Occupies middle part of cochlear canal
3 walls
- Floor – basilar membrane
- Roof – vestibular membrane
- Outer wall – bony
Organ of Corti lies on basilar membrane
Saccule and utricle
Lies in vestibule
Dilated sacs
Reuniens duct:
Connects cochlear duct with saccule
Utriculosaccular duct:
Connects saccule with utricle
Maculae: Thickening of saccule and utricle
Ductus endolymphaticus
Semicircular ducts
Three ducts
- Superior/anterior
- Posterior
- Lateral
Ampulla – dilated terminal part
Ampullary crest/ cupola

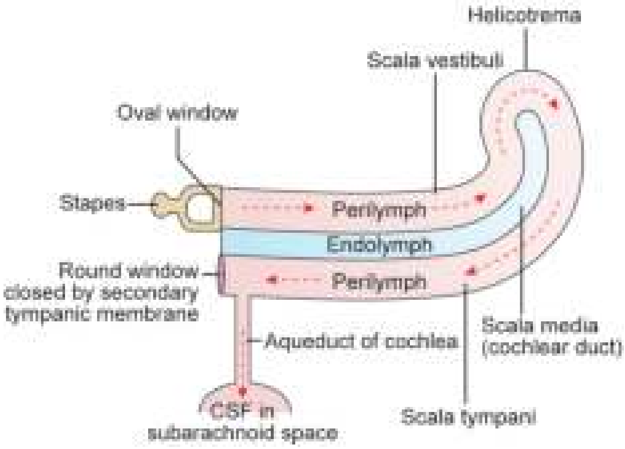

Helicotrema
Scala vestibuli
Oval window
Stapes
Perilymph
Endolymph
Perilymph
Round window closed by secondary tympanic membrane
Aqueduct of cochlea
Scala media (cochlear duct)
CSF in subarachnoid space
Scala tympani

Fig. 18.24: Cochlear duct, scala vestibulli, and scala tympani (CSF: Cerebrospinal fluid)

3. A spiral ridge of the bone, the ***spiral lamina***, projects from the modiolus and partially divides the cochlear canal into the scala vestibuli above, and the scala tympani below. These relationships apply to the lowest part or basal turn of the cochlea. The division between the two passages is completed by the ***basilar membrane***.
4. The scala vestibuli communicates with the scala tympani at the apex of the cochlea by a small opening, called the ***helicotrema***.

Vestibule

1. This is the central part of the bony labyrinth. It lies medial to the middle ear cavity. Its lateral wall opens into the middle ear at the fenestra vestibuli which is closed by the footplate of the stapes.
2. Three semicircular canals open into its posterior wall. The medial wall is related to the internal acoustic meatus, and presents the ***spherical recess*** in front, and the ***elliptical recess*** behind. The two recesses are separated by a ***vestibular crest*** which splits inferiorly to enclose the ***cochlear recess***.
3. Just below the elliptical recess, there is the opening of a diverticulum, the *aqueduct of the vestibule* which opens at a narrow fissure on the posterior aspect of the

petrous temporal bone, posterolateral to the internal acoustic meatus. It is plugged in life by the *ductus endolymphaticus* and a vein; no perilymph escapes through it.

Semicircular Canals

There are three bony semicircular canals: (1) An anterior or superior, (2) posterior, and (3) lateral; each has two ends. They lie posterosuperior to the vestibule, and are set at right angles to each other. Each canal describes two-thirds of a circle, and is dilated at one end to form the ***ampulla***. These three canals open into the vestibule by *five* openings (Fig. 18.25).

1. ***Anterior* or *superior semicircular canal*** lies in a vertical plane at right angles to the long axis of the petrous temporal bone. It is convex upwards. Its position is indicated by the arcuate eminence seen on the anterior surface of the petrous temporal bone. Its ampulla is situated anterolaterally. Its posterior end unites with the upper end of the posterior canal to form the ***crus commune*** which opens into the medial wall of the vestibule.
2. ***Posterior semicircular canal*** also lies in a vertical plane parallel to the long axis of the petrous temporal bone. It is convex backwards. Its ampulla lies at its lower end. The upper end joins the anterior canal to form the crus commune.
3. ***Lateral semicircular canal*** lies in the horizontal plane with its convexity directed posterolaterally. The ampulla lies anteriorly, close to the ampulla of the anterior canal.

Note: The lateral semicircular canals of the two sides lie in the same plane. The anterior canal of one side lies in the plane of the posterior canal of the other side.

MEMBRANOUS LABYRINTH

It is a membrane-bound cavity filled with ***endolymph***.

The epithelium of the membranous labyrinth is specialized to form the following receptors:

1. For sound, i.e. ***organ of Corti***
2. For static balance, the ***maculae***
3. For kinetic balance, the ***cristae***.

Like the bony labyrinth, the membranous labyrinth also consists of three main parts:

1. Spiral duct of the cochlea or organ of Corti, anteriorly.
2. Utricle and saccule with maculae, the organs of static balance, within the vestibule.
3. Semicircular ducts with cristae, the organs of kinetic balance, posteriorly (Fig. 18.26).

Competency:
AN43.3 Identify, describe and draw microanatomy of olfactory epithelium, eyelid, lip, sclerocorneal junction, optic nerve, cochlea—organ of Corti, pineal gland.

Microanatomy of cochlea and organ of corti is given here. For microanatomy of other structures please refer to appropriate chapters.

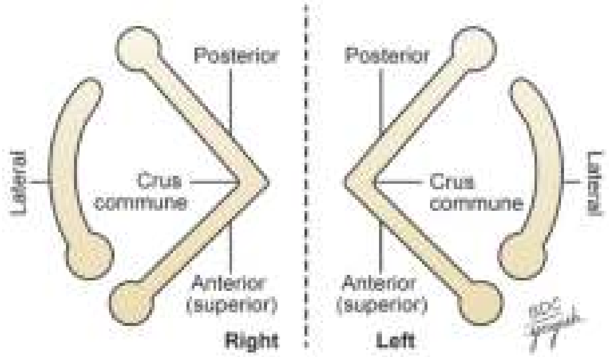


Fig. 18.25: Semicircular canals

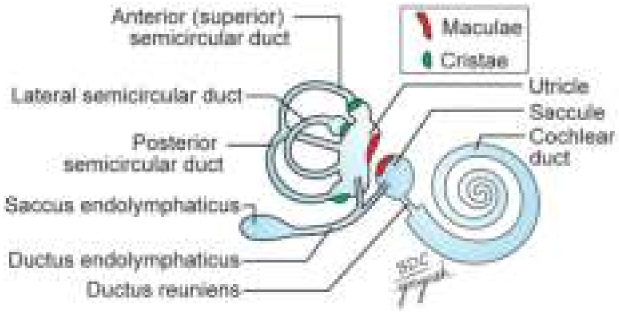


Fig. 18.26: Parts of the membranous labyrinth (as seen from the lateral side)

Duct of the Cochlea or the Scala Media

1. The spiral duct occupies the middle part of the cochlear canal between the scala vestibuli and the scala tympani (Fig. 18.27).
2. It is triangular in cross-section. It has three walls:
   - *Floor* is formed by the *basilar membrane*
   - *Roof* by the *vestibular* or *Reissner's membrane*
   - Outer wall by the bony wall of the cochlea.
3. The ***basilar membrane*** supports the spiral ***organ of Corti*** which is the end organ for hearing. It comprises rods of Corti and hair cells. Hair is embedded in a gelatinous membrane called the ***membrana tectoria***. The organ of Corti is innervated by peripheral processes of bipolar cells located in the ***spiral ganglion***. This ganglion is located in the spiral canal present within the modiolus at the base of the spiral lamina. The central processes of the ganglion cells form the cochlear nerve.
4. Posteriorly, the duct of the cochlea is connected to the saccule by a narrow ***ductus reunions***.

Note: The sound waves reaching the endolymph through the vestibular membrane make appropriate parts of the basilar membrane vibrate, so that different parts of the organ of Corti are stimulated by different frequencies of sound. The loudness of the sound depends on the amplitude of vibration.

Saccule and Utricle

1. The ***saccule*** lies in the anteroinferior part of the vestibule, and is connected to the basal turn of the cochlear duct by the ductus reunions.

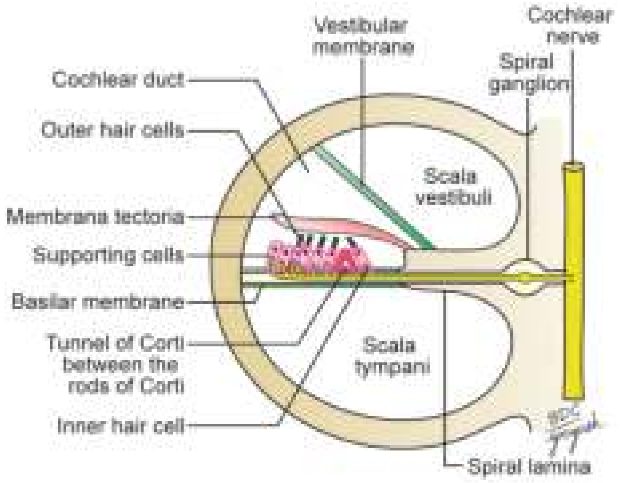

Vestibular membrane
Cochlear nerve
Spiral ganglion
Cochlear duct
Outer hair cells
Scala vestibuli
Membrana tectoria
Supporting cells
Basilar membrane
Tunnel of Corti between the rods of Corti
Scala tympani
Inner hair cell
Spiral lamina

Fig. 18.27: Schematic section through one turn of the cochlea

2. The ***utricle*** is larger than the saccule and lies in the posterosuperior part of the vestibule. It receives *the ends of three* semicircular ducts through *five openings*. The duct of the saccule unites with the duct of the utricle to form the ***ductus endolymphaticus***. The ductus endolymphaticus ends in a dilatation, the ***saccus endolymphaticus***. The ductus and saccus occupy the aqueduct of the vestibule.
3. The medial walls of the saccule and utricle are thickened to form a ***macula*** in each chamber. The maculae are end organs that give information about the position of the head. They are static balance receptors. They are supplied by peripheral processes of neurons in the vestibular ganglion.
4. Saccule gets stimulated by vertical linear motions, e.g. going in 'lift'. Utricle gets stimulated by horizontal linear motion, e.g. going in car.

Semicircular Ducts

1. The three semicircular ducts lie within the corresponding bony canals. Each duct has an ampulla corresponding to that of the bony canal.
2. In each ampulla, there is an end organ called the ampullary crest or ***crista*** or cupola. Cristae respond to pressure changes in the endolymph caused by movements of the head.

Blood Supply of Labyrinth

The arterial supply is derived mainly from the labyrinthine branch of the basilar artery which accompanies the vestibulocochlear nerve; and partly from the stylomastoid branch of the posterior auricular artery.

The labyrinthine vein drains into the superior petrosal sinus or the transverse sinus. Other inconstant veins emerge at different points and open separately into the superior and inferior petrosal sinuses and the internal jugular vein.

VESTIBULOCOCHLEAR NERVE

Cochlear Pathway

Vestibulocochlear nerve comprises hearing and vestibular parts. The first neurons of the pathway are located in the spiral ganglion. They are bipolar. Their peripheral processes innervate the spiral organ of Corti, while central processes form the cochlear nerve. This nerve terminates in the dorsal and ventral cochlear nuclei. From cochlear nuclei, fibres travel through pons, midbrain, thalamus and internal capsule to reach auditory area in temporal pole (Fig. 18.28).

Vestibular Pathway

The vestibular receptors are the maculae of the saccule and utricle (for static balance) and in the crista of the ampullaris of semicircular ducts (for kinetic balance).

Fibres from cristae of anterior and lateral semicircular canals and some fibres from the two maculae lie in superior vestibular area of internal acoustic meatus.

Fibres of crista of posterior semicircular canal lie in foramen singulare.

Most of the fibres from maculae of utricle and saccule lie in inferior vestibular area.

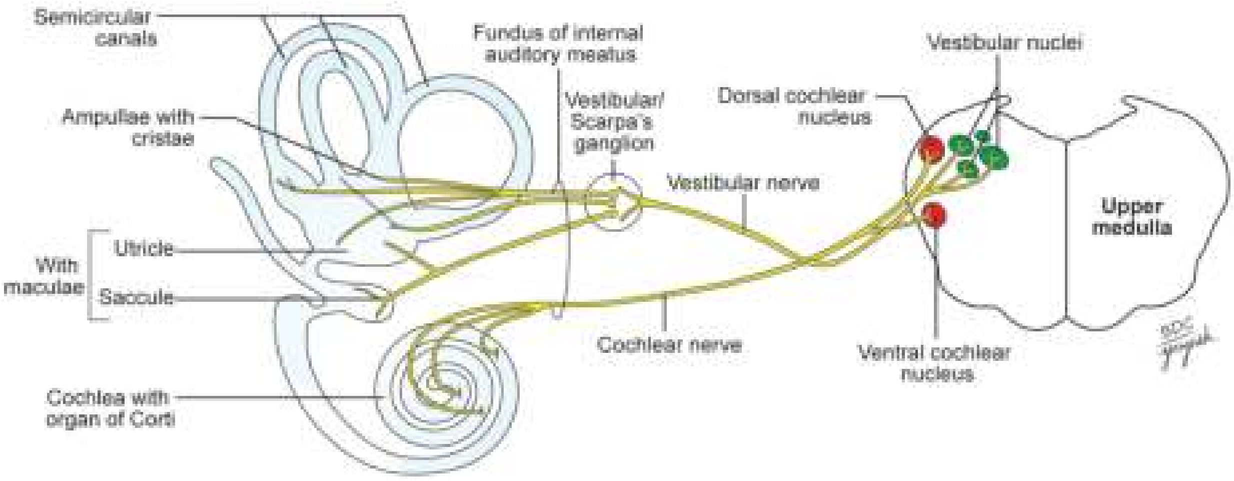
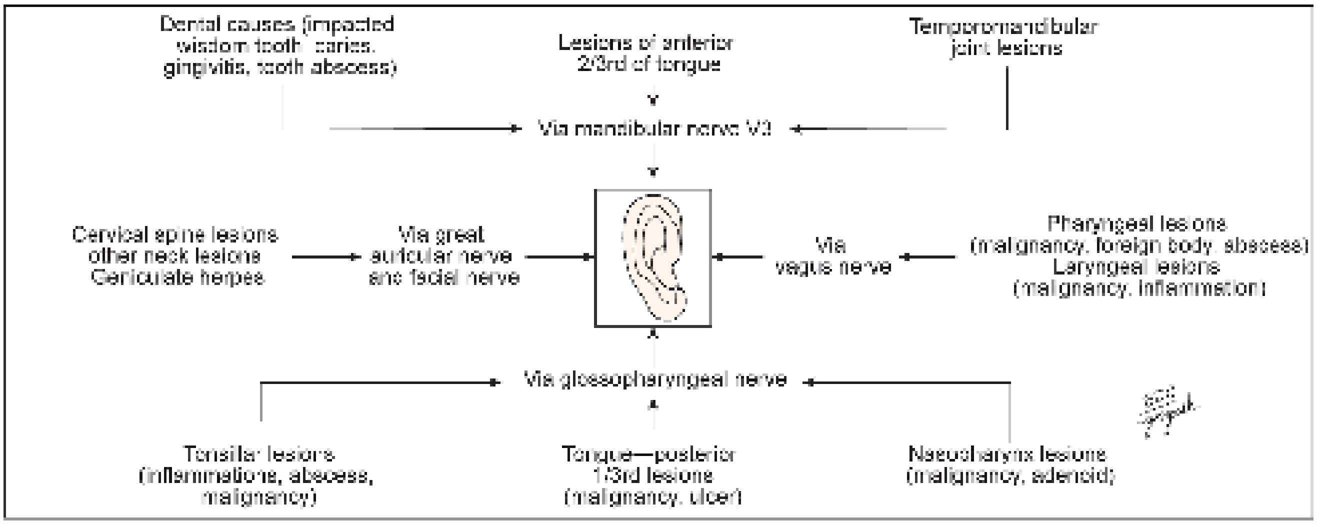

Semicircular canals
Fundus of internal auditory meatus
Vestibular nuclei
Ampullae with cristae
Vestibular/ Scarpa's ganglion
Dorsal cochlear nucleus
Vestibular nerve
Upper medulla
With maculae
Utricle
Saccule
Cochlear nerve
Ventral cochlear nucleus
Cochlea with organ of Corti

Fig. 18.28: Course of vestibulocochlear nerve

Flowchart 18.5: Reasons of earache


Dental causes (impacted wisdom tooth, caries, gingivitis, tooth abscess)
Lesions of anterior 2/3rd of tongue
Temporomandibular joint lesions
Via mandibular nerve V3
Cervical spine lesions other neck lesions Geniculate herpes
Via great auricular nerve and facial nerve
Via vagus nerve
Pharyngeal lesions (malignancy, foreign body, abscess)
Laryngeal lesions (malignancy, inflammation)
Via glossopharyngeal nerve
Tonsilar lesions (inflammations, abscess, malignancy)
Tongue—posterior 1/3rd lesions (malignancy, ulcer)
Nasopharynx lesions (malignancy, adenoid)

These three nerve divisions are peripheral processes of bipolar neurons of the vestibular ganglion. This ganglion is situated in the internal acoustic meatus. The central processes arising from the neurons of the ganglion form the vestibular nerve which ends in the vestibular nuclei.

These nuclei send fibres:

a. To the archicerebellum through the inferior cerebellar peduncle.
b. To the motor nuclei of the brainstem (chiefly of the III, IV, VI and XI nerves)

Through the vestibular pathway, the impulses arising in the labyrinth can influence the movements of the eyes, the head, the neck and the trunk.

CLINICAL ANATOMY

- Endolymph is produced by striae vascularis. This process requires melanocytes. The disorders of melanocytes, i.e. albinism, are associated with deafness.
- Acoustic neuroma is a tumour of Schwann cells of VIII nerve. If neuroma extends into internal auditory meatus, VII nerve will get pressed. There will be VIII nerve paralysis and VII nerve paralysis as well.
- Reasons of earache are depicted in Flowchart 18.5.

DEVELOPMENT

External auditory meatus: Dorsal part of 1st ectodermal cleft.

Auricle: Tubercles appearing on 1st and 2nd branchial arches around the opening of external auditory meatus.

Middle ear cavity and auditory tube: Tubotympanic recess.

Ossicles

a. *Malleus and incus:* *From 1st arch cartilage.*
b. *Stapes:* *From 2nd arch cartilage.*

Muscles

a. *Tensor tympani:* *From 1st pharyngeal arch mesoderm.*
b. *Stapedius:* *From 2nd pharyngeal arch mesoderm.*

Membranous labyrinth: From ectodermal vesicle on each side of hindbrain vesicle. Organ of Corti—ectodermal.

Video 3.18 Ear

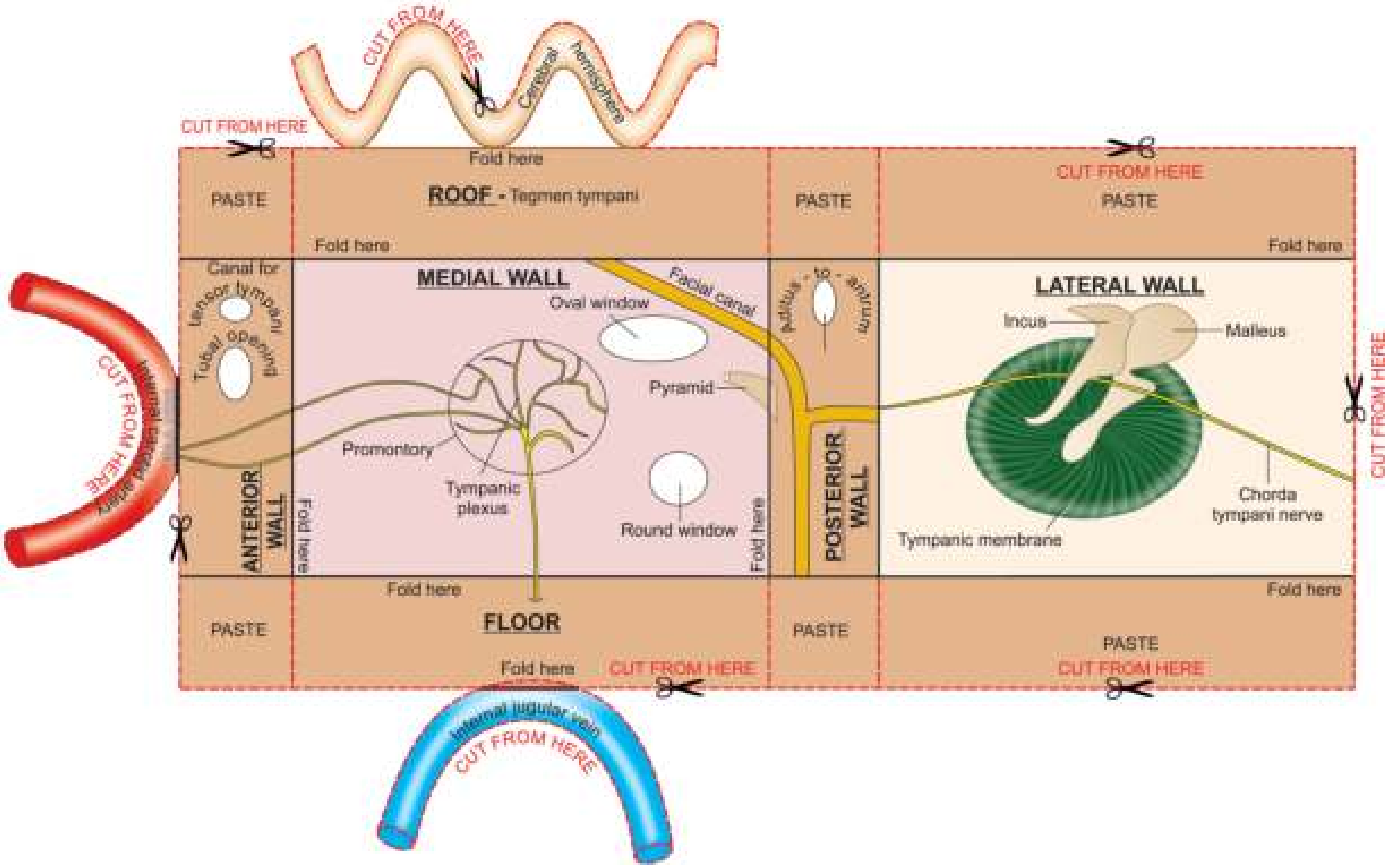
Facts to Remember

- Tympanic membrane develops from ectoderm, mesoderm and endoderm.
- Outer aspect of tympanic membrane is supplied by part of V and X nerves.
- Malleus and incus develop from 1st pharyngeal arch, while stapedius develops from second pharyngeal arch.
- Tensor tympani develops from 1st arch and is supplied by V3, while stapedius develops from 2nd arch and is supplied by VII nerve.
- Eustachian tube equalizes the pressure on both sides of the tympanic membrane. This tube connects the nasopharynx to the anterior wall of middle ear.
- Malleus, incus and stapes are *bone within bone*, as these 3 bony ossicles lie within the petrous temporal bone.
- There are 2 synovial joints between these three bony ossicles, which are fully developed at birth.
- One may slowly become deaf to soft sounds, if one is continuously exposed to a lot of loud sounds.

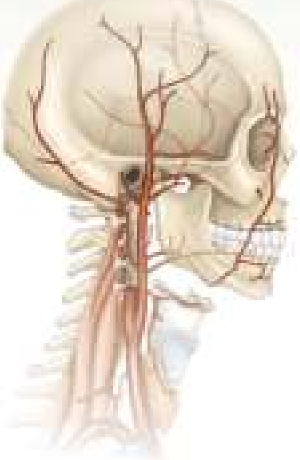
BDC's Anatomy *e*-book

1. Noise pollution - poem
2. Organ of Corti
3. Macula
4. Ampullary crests
5. Molecular regulation
6. Further reading
7. Viva voce questions

RIGHT MIDDLE EAR



CUT FROM HERE
Cerebral hemisphere
CUT FROM HERE
PASTE
Fold here
ROOF - Tegmen tympani
PASTE
CUT FROM HERE
PASTE
Fold here
Fold here
Canal for tensor tympani
Tubal opening
MEDIAL WALL
Oval window
Facial canal
Aditus - to - antrum
LATERAL WALL
Incus
Malleus
Pyramid
Promontory
Tympanic plexus
Round window
Internal carotid artery
CUT FROM HERE
ANTERIOR WALL
Fold here
Fold here
POSTERIOR WALL
Tympanic membrane
Chorda tympani nerve
CUT FROM HERE
Fold here
Fold here
PASTE
FLOOR
PASTE
PASTE
Fold here
CUT FROM HERE
CUT FROM HERE
Internal jugular vein
CUT FROM HERE



Chapter 19

Eyeball

Eye is a peripheral organ of vision located in the bony orbit. The eye is spherical in shape (25 mm in diameter). Its movements are facilitated by six extraocular muscles.

Tunics of Eyeball

The wall of eyeball consists of three structural layers (Fig. 19.1):

1. Outer fibrous layer – sclera and cornea
2. Middle vascular coat/uvea – choroid, ciliary body and iris
3. Inner nervous coat – retina.

The eyeball (= *oculus* in Latin and *ophthalmos* in Greek) has three chambers as follows:

1. Anterior chamber: Space between cornea and iris (Fig. 19.1)
2. Posterior chamber: Space between iris and anterior surface of lens
3. Vitreous chamber: Space between posterior surface of lens and retina.

The anterior and posterior chambers contain aqueous humour (watery fluid), whereas posterior compartment contains gel-like vitreous body. The cornea, lens, aqueous humour, and vitreous body are transparent refractive media of eyeball.

Competency:
AN41.1 Describe and demonstrate parts and layers of eyeball.

OUTER COAT

SCLERA

The sclera (*skleros* = hard) is opaque and forms the posterior five-sixths of the eyeball.

Structure

1. It is composed of dense fibrous tissue which is firm and maintains the shape of the eyeball.
2. It is thickest behind, near the entrance of the optic nerve, and thinnest about 6 mm behind the ***sclerocorneal junction*** where the recti muscles are inserted. However, it is weakest at the entrance of the optic nerve. Here the sclera shows numerous perforations for passage of fibres of the optic nerve. Because of its sieve-like appearance, this region is called the ***lamina cribrosa*** (*crib* = sieve).
3. The *outer surface* of the sclera is white and smooth, it is covered by Tenon's capsule. Its anterior part is covered by conjunctiva through which it can be seen as the white of the eye.
4. The *inner surface* is brown and grooved for the ciliary nerves and vessels. It is separated from the choroid by the ***perichoroidal space*** which contains a delicate cellular tissue, termed the ***suprachoroidal lamina*** or *lamina fusca of the sclera.*
5. The sclera is continuous anteriorly with the cornea at the *sclerocorneal junction or limbus* (Fig. 19.1). The deep part of the limbus contains a circular canal, known as the *sinus venosus sclerae or the* ***canal of Schlemm***. The aqueous humour drains into the anterior scleral or ciliary veins through this sinus.
6. The sclera is fused posteriorly with the *dural sheath of the optic nerve.* It provides insertion to the extrinsic muscles of the eyeball: The recti in front of the equator, and the oblique muscles behind the equator.

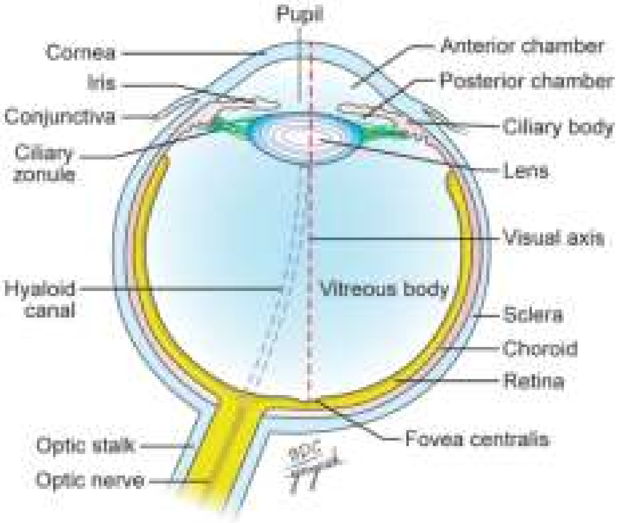


Fig. 19.1: Sagittal section through the eyeball

Functions of Sclera

1. *Support*: It helps to maintain the shape of the eyeball.
2. *Protection*: It protects internal structures.
3. *Attachments*: It provides attachment to muscles that move the eyeball.

Structures Piercing Sclera

The sclera is pierced by a number of structures:

a. *Optic nerve* pierces it a little inferomedial to the posterior pole of the eyeball.
b. *Ciliary nerves and arteries* pierce it around the entrance of the optic nerve.
c. *Anterior ciliary arteries*, derived from muscular arteries to the recti, pierce it near the limbus.
d. Four *venae vorticosae* or the choroid veins pass out through the sclera just behind the equator (Fig. 19.2).

Note: The sclera is almost avascular. However, the loose connective tissue between the conjunctiva and sclera called as the *episclera* is vascular.

DISSECTION

Use the fresh eyeball of the goats for this dissection. Clean the eyeball by removing all the tissues from its surface. Cut through the fascial sheath around the margin of the cornea. Clean and identify the nerve with posterior ciliary arteries and ciliary nerves close to the posterior pole of the eyeball. Identify venae vorticosae piercing the sclera just behind the equator.

Incise only the sclera at the equator and then cut through it all around and carefully strip it off from the choroid. Anteriorly, the ciliary muscles are attached to the sclera, offering some resistance. As the sclera is steadily separated, the aqueous humour will escape from the anterior chamber of the eye. On dividing the optic nerve fibres, the posterior part of sclera can be removed.

CORNEA

The cornea is transparent. It replaces the sclera over the anterior one-sixth of the eyeball. Its junction with the sclera is called the *sclerocorneal junction or limbus* (Fig. 19.1).

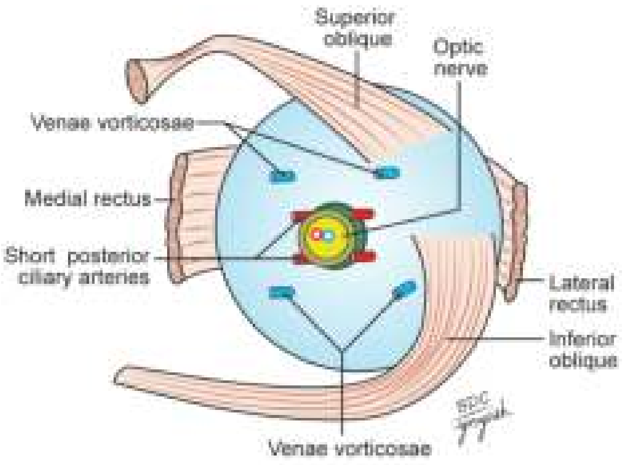


Fig. 19.2: Structures piercing the posterior aspect of the eyeball

Structure

1. The cornea is more convex than the sclera, but the curvature diminishes with age. It is separated from the iris by a space called the *anterior chamber of the eye*.
2. The cornea is avascular and is nourished by lymph which circulates in the numerous corneal spaces and by the lacrimal fluid.
3. It is supplied by branches of the ophthalmic nerve and the short ciliary nerves (through the ciliary ganglion). Pain is the only sensation aroused from the cornea.

Competency:

AN43.2 Identify, describe and draw the microanatomy of pituitary gland, thyroid, parathyroid gland, tongue, salivary glands, tonsil, epiglottis, cornea, retina.

Microanatomy of cornea is described here. For the other organs, please see appropriate chapters.

Histology/Microanatomy

Cornea is a transparent, colourless, avascular structure that has five layers, before backwards (Plate 19.1 and Flowchart 19.1):

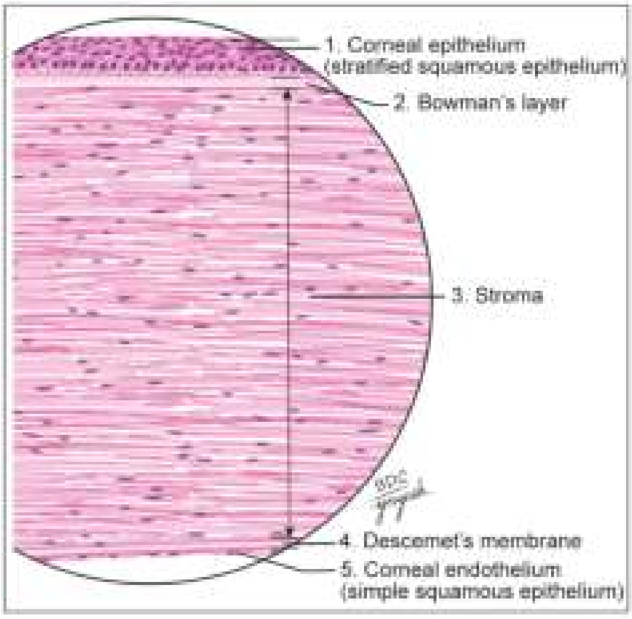
1. *Corneal epithelium* consists of nonkeratinized stratified squamous epithelium.
2. *Bowman's membrane*/anterior limiting lamina is thickened basal lamina of corneal epithelium.
3. *Corneal stroma* consists of layers of collagen fibrils having orthogonal array and few fibroblasts.
4. *Descemet's membrane*/posterior limiting lamina is the thickened basal lamina of corneal endothelium.
5. *Posterior endothelium* consists of simple squamous (low cuboidal) epithelium.

CLINICAL ANATOMY

- After the injury, swelling of cornea causes disruption of orthogonal array of cornea. This leads to corneal opacity.
- In corneal inflammation, lymphocytes enter corneal stroma from blood vessels that lie at sclerocorneal junction (Plate 19.2).
- Bowman's membrane cannot regenerate but Descemet's membrane can regenerate.
- As cornea is an avascular structure, severely damaged cornea can be easily treated with corneal transplantation.
- ***Corneal opacity***: The injury to cornea may cause opacity that may interfere with vision.
- *Corneal transplantation*: The lack of vascularity and lymph vessels make the corneal grafting suitable. The cornea is successfully grafted from one person to the other.
- ***Corneal reflex***: The cornea is highly sensitive to touch and pain.

  Procedure to elicit: Touch gently the cornea with wisp of cotton wool and observe the blinking of eyelids.

Plate 19.1: Histology of cornea


1. Corneal epithelium (stratified squamous epithelium)
2. Bowman's layer
3. Stroma
4. Descemet's membrane
5. Corneal endothelium (simple squamous epithelium)
BDC

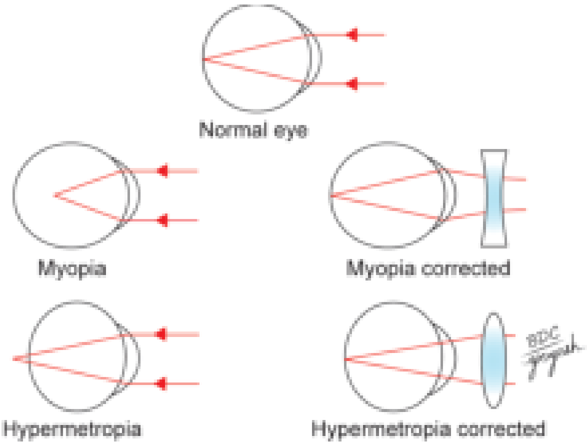

Normal eye
Myopia
Myopia corrected
Hypermetropia
Hypermetropia corrected
BDC

Fig. 19.3: Optical defects

Pathway: Ophthalmic nerve (afferent neurons) → main sensory nucleus of trigeminal nerve in midbrain → reticular formation → both the facial nerves (efferent neurons).

- The anteroposterior diameter of the eyeball and shape and curvature of the cornea determine the focal point. Changes in these result in myopia or shortsightedness, hypermetropia or longsightedness (Fig. 19.3).

DISSECTION

Identify the cornea. Make an incision around the corneoscleral junction and remove the cornea so that the iris is exposed for examination. Identify the middle coat comprising choroid, ciliary body and iris deep to the sclera. Lateral to iris is the ciliary body with ciliary muscles and ciliary processes.

Strip off the iris, ciliary processes, anterior part of choroid. Remove the lens and put it in water. As the lens is removed, the vitreous body also escapes. Only the posterior part of choroid and subjacent retina is left.

MIDDLE COAT (VASCULAR COAT OR UVEA)

Deep to sclera, there is a vascular coat of eyeball. It consists of:

1. Choroid
2. Ciliary body, and
3. Iris.

CHOROID

Choroid is a thin pigmented layer which separates the posterior part of the sclera from the retina.

Structure

The choroid consists of two layers: Choriocapillary layer and Bruch's membrane.

1. ***Choriocapillary layer:*** It lies superficial to Bruch's membrane. It consists of a network of blood vessels and supportive collagen fibres. It also contains many pigmented cells that give dark colour to choroid. The outer vascular lamina of choriocapillary layer has larger vessels, whereas inner capillary lamina (choroidocapillaries) contains a network of capillaries. Choriocapillary layer is externally supported by a nonvascular connective tissue coat called suprachoroid lamina or lamina fusca.
2. ***Bruch's membrane* (*lamina vitrea*):** It lies between choriocapillary layer and retina. It is a thin amorphous refractive layer. It consists of layers of elastic and collagen fibres. The choroid extends from optic nerve to ***ora serrata***.

Blood Supply

1. *Arteries*: Choroid is supplied by short ciliary arteries, which pierce the sclera around the optic nerve.

Flowchart 19.1: Histology of cornea

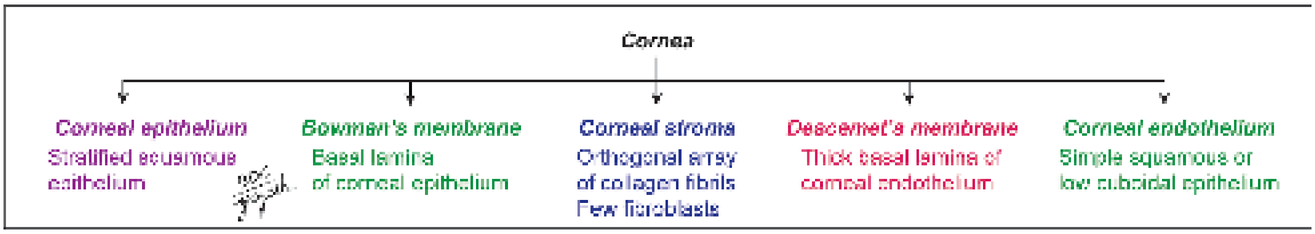
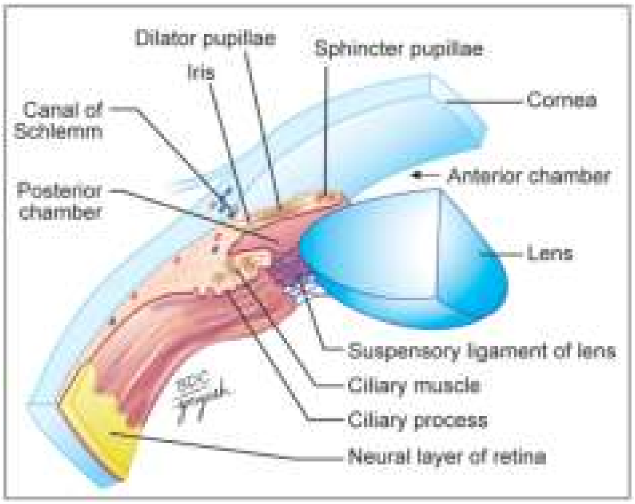

Cornea
Corneal epithelium
Stratified squamous epithelium
Bowman's membrane
Basal lamina of corneal epithelium
Corneal stroma
Orthogonal array of collagen fibrils
Few fibroblasts
Descemet's membrane
Thick basal lamina of corneal endothelium
Corneal endothelium
Simple squamous or low cuboidal epithelium
BDC

Plate 19.2: Sclerocorneal junction, ciliary body and suspensory ligament of lens



2. *Veins*: They are arranged in the form of whorls. These veins converge to form 4 or 5 venae vorticosae, which pierce the sclera just behind the equator to open into the ophthalmic veins.

***Competencies*:**

AN41.3 Describe the position, nerve supply and actions of intraocular muscles.

AN43.3 Identify, describe and draw microanatomy of olfactory epithelium, microanatomy of iridio eyelid, lip, sclerocorneal junction, optic nerve, cochlea— organ of Corti, pineal gland.

CILIARY BODY

The ciliary body is the thickened circular anterior portion of vascular coat of eyeball. It posteriorly continues with the choroid and anteriorly with iris. It is connected to lens by suspensory ligaments.

Parts of Ciliary Body

1. The ciliary body consists of *ciliaris* muscles and vascular connective tissue (Plate 19.2). Ciliaris muscle consists of three functional groups of smooth muscle fibres as follows:
   - Longitudinal portion that helps to open iridocorneal angle and facilitate drainage of aqueous humour.
   - Oblique portion that causes flattening of lens during distant vision.
   - Circular portion that reduces tension of lens during accommodation for near vision.
2. *Ciliary processes*: These are approximately 75 thickenings of ciliary body that are covered by double layers of columnar epithelium cells (ciliary epithelium). Ciliary epithelium secretes aqueous humour and maintains blood–aqueous barrier. Outer cell layer of epithelium is pigmented, whereas inner cell layer secretes aqueous humour. Zonular fibres arise from suspensory ligament of the lens. *Ciliary ring* is an outer fibrous ring, which is continuous with the choroid.

Functions

1. *Accommodation*: The main function of ciliary body is to focus the lens for near vision.

   Mechanism: The ciliary muscle as a whole acts as a sphincter, therefore, when its muscle fibres, both radial and circular contract, the choroid is pulled toward the lens reducing the tension on the suspensory ligaments. This allows the lens to assume a more spherical form because of its own elastic nature. Thus, the lens can cause more refraction needed for accommodation.
2. Production of aqueous humour.
3. Maintenance of blood – aqueous barrier.

IRIS

1. The iris is the anteriormost part of vascular coat of eyeball. Iris is attached peripherally to sclera, at about 2 mm posterior to corneoscleral junction.
2. *Pupil*: Central aperture of the iris is called pupil.
3. Iris forms a contractile diaphragm in front of lens that controls entry of light in the eyeball.

Structure of Iris

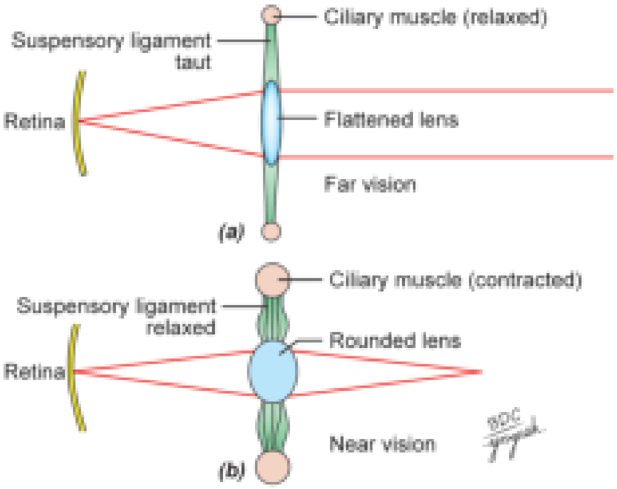
1. Iris consists of two parts:
   - Posterior pigmented epithelium
   - Anterior connective tissue stroma
2. Posterior pigmented epithelium consists of two layers: Posterior densely pigmented epithelium and anterior pigmented myoepithelial cells.
3. Stroma of iris consists of smooth muscle fibres, fibroblasts, melanocytes, connective tissue fibres, and blood vessels.
4. Smooth muscle fibres are arranged as:
   a. Circumferentially oriented *sphincter pupillae* muscle
   b. Longitudinally (radially) oriented *dilator pupillae* muscle
5. Numerous melanocytes are present in the stroma of iris. These melanocytes decide the colour of iris.

CLINICAL ANATOMY

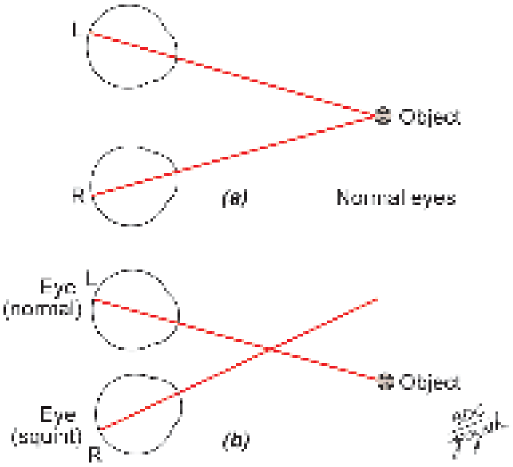
- While looking at infinite far, the light rays run parallel; ciliary muscle is relaxed, suspensory ligament is tense and lens is flat (Fig. 19.4a).
- While reading a book, the ciliary muscles contract and suspensory ligament is relaxed making the lens more convex (Fig. 19.4b).
- Human vision is coloured, binocular and three dimensional. Normally, right and left eyes are focused on one object (Fig. 19.5a). In squinting, fixing eye (F) focuses on the object, but the squinting eye (S) is 'turned inwards' resulting in a convergent squint (Fig. 19.5b).

INNER COAT/RETINA

1. This is the thin, delicate innermost layer of the eyeball. It is continuous posteriorly with the optic nerve. The outer surface of the retina (formed by pigment cells) is attached to the choroid, while the inner surface is in


Ciliary muscle (relaxed)
Suspensory ligament taut
Retina
Flattened lens
Far vision
(a)
Ciliary muscle (contracted)
Suspensory ligament relaxed
Rounded lens
Retina
Near vision
(b)

Figs 19.4a and b: (a) Relaxed ciliary muscles with flattened lens and (b) contracted ciliary muscles with round lens


L
Object
R
(a)
Normal eyes
Eye (normal)
L
Object
Eye (squint)
R
(b)

Figs 19.5a and b: (a) Normal eyes and (b) in squinting eyes

contact with the hyaloid membrane (of the vitreous). Opposite the entrance of the optic nerve (inferomedial to the posterior pole), there is a circular area known as the *optic disc*. It is 1.5 mm in diameter.

2. The retina diminishes in thickness from behind forwards and is divided into optic, ciliary and iridial parts. The *optic part of the retina* contains nervous tissue and is sensitive to light. It extends from the optic disc to the posterior end of the ciliary body. The anterior margin of the optic part of the retina forms a wavy line called the **ora serrata**.
3. Beyond the ora serrata, the retina is continued forwards as a thin, non-nervous insensitive layer that covers the ciliary body and iris, forming the ***ciliary and iridial parts of the retina***. These parts are made up of two layers of epithelial cells.
4. The depressed area of the optic disc is called the ***physiological cup***. It contains no rods or cones and is, therefore, insensitive to light, i.e. it is the ***physiological blind spot***. At the posterior pole of the eye 3 mm lateral to the optic disc, there is another depression of similar size, called the ***macula lutea***. It is avascular and yellow in colour. The centre of the macula is further depressed to form the ***fovea centralis***. This is the thinnest part of the retina. It contains cones only, and is the site of maximum acuity of vision.
5. The rods and cones are the light receptors of the eye.

Note: The *rods* contain a pigment called ***visual purple***. They can respond to dim light (*scotopic vision*). The periphery of the retina contains only rods, but the fovea has none at all. The *cones* respond only to bright light (*photopic vision*) and are sensitive to colour. The fovea centralis has only cones. Their number diminishes towards the periphery of the retina.

6. The retina is composed of ten layers (Plate 19.3):
   i. Retinal pigmented epithelium (RPE)
   ii. Layer of rods and cones
   iii. Outer limiting membrane
   iv. Outer nuclear layer
   v. Outer/external plexiform layer
   vi. Inner nuclear layer
   vii. Inner plexiform layer
   viii. Ganglion cell layer
   ix. Layer of optic nerve fibers
   x. Inner limiting membrane.
7. ***Blood supply*:** The retina is supplied by the ***central artery***. This is an end artery. In the optic disc, it divides into an upper and a lower branch, each giving off nasal and temporal branches. The artery supplies the deeper layers of the retina up to the bipolar cells. The rods and cones are supplied by diffusion from the capillaries of the choroid. The retinal veins run with the arteries (Fig. 19.6).

Competency:

AN43.2 Identify, describe and draw the microanatomy of pituitary gland, thyroid, parathyroid gland, tongue, salivary glands, tonsil, epiglottis, cornea, retina.

Microanatomy of retina is given here. For rest of the topics, please see respective chapters.

CLINICAL ANATOMY

- ***Retinal detachment*** occurs between outer single pigmented layer and inner nine nervous layers. Actually, it is an inter-retinal detachment. Silicone sponge is put over the detached retina, which is kept in position by a 'band' (Figs 19.7a and b).
- The central artery of retina is an end-artery. Blockage of the artery leads to sudden blindness.

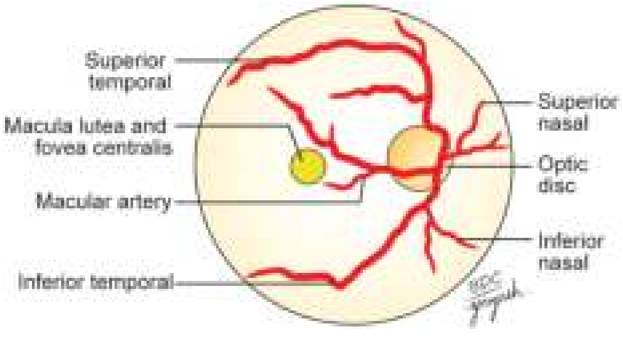
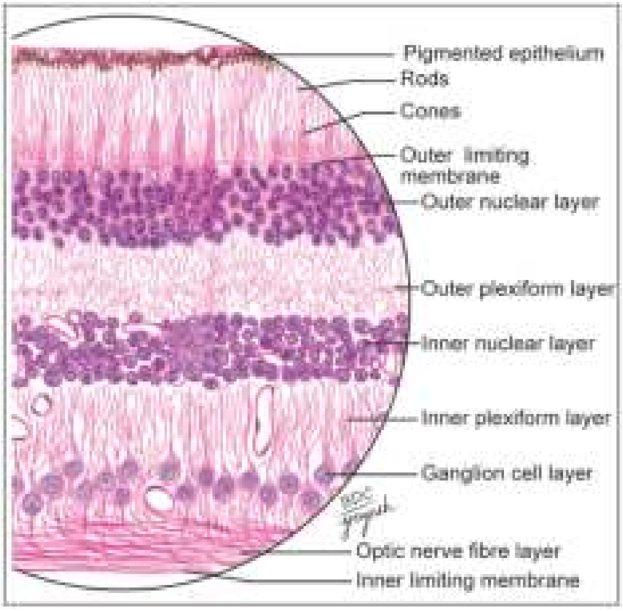
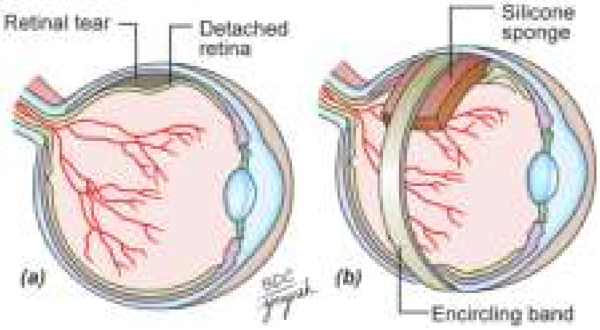

Superior temporal
Macula lutea and fovea centralis
Macular artery
Inferior temporal
Superior nasal
Optic disc
Inferior nasal

Fig. 19.6: Distribution of central artery of the retina

Plate 19.3: Histological layers of the retina





Figs 19.7a and b: (a) Detached retina and (b) banding of the retina

AQUEOUS HUMOUR

1. This is a clear fluid which fills the space between the cornea in front and the lens behind. It is called the anterior segment. This segment is divided by the iris into anterior and posterior chambers which freely communicate with each other through the pupil.
2. The aqueous humour is secreted into the posterior chamber from the capillaries in the ciliary processes. It passes into the anterior chamber through the pupil. From the anterior chamber, it is drained into the anterior ciliary veins through the spaces of the iridocorneal angle or angle of anterior chamber (located between the fibres of the ligamentum pectinatum) and the canal of Schlemm.

Competency:
AN41.2 Describe the anatomical aspects of cataract, glaucoma and central retinal artery occlusion.

CLINICAL ANATOMY

- Interference with the drainage of the aqueous humour into the canal of Schlemm results in an increase of intraocular pressure (***glaucoma***). This produces cupping of the optic disc and pressure atrophy of the retina causing blindness.
- The intraocular pressure is due chiefly to the aqueous humour which maintain the constancy of the optical dimensions of the eyeball. The aqueous is rich in ascorbic acid, glucose and amino acids, and nourishes the avascular tissues of the cornea and lens.

LENS

The crystalline lens of eye is a transparent, biconvex, avascular structure. Lens is suspended from ciliary body by zonular fibres (Fig. 19.8). Lens lies between aqueous humour and vitreous humour.

Structure

The lens has the following three components:

1. **Lens capsule:** It capsule is a transparent homogenous basal lamina of lens epithelium. The capsule consists of type IV collagen fibres and glycoproteins. It is produced by lens epithelium.
2. **Lens epithelium:** Deep to capsule, anterior surface of lens is covered by a layer of *cuboidal epithelium*. This is also called *anterior lens epithelium* or subcapsular epithelium. Towards periphery, cells of epithelium become progressively longer and ultimately get converted into long fibres that form substance of the lens.
3. **Lens fibres (lens fibre cells):** The lens epithelium develops to form lens fibres. These are composed of soluble proteins called *crystallins*.

Note:

- The lens is circular in outline and has a diameter of 1 cm. The central points of the anterior and posterior surfaces are called the anterior and posterior *poles* (Fig. 19.8). The line connecting the poles constitutes the *axis* of the lens, while the marginal circumference is termed the *equator.* The chief advantage of the lens is that it can vary its dioptric power. It contributes about 15 dioptres to the total of 58 dioptric power of the eye.
- A dioptre is the inverse of the focal length in meters. A lens having a focal length of half meter has a power of two dioptres.
- The posterior surface of the lens is more convex than the anterior. The anterior surface is kept flattened by the tension of the suspensory ligament. When the ligament is relaxed by contraction of the ciliary muscle, the anterior surface becomes more convex due to elasticity of the lens substance.
- The *suspensory ligament of the lens* (or the zonule of Zinn) retains the lens in position and its tension keeps the anterior surface of the lens flattened. The ligament is made up of a series of fibres which are attached peripherally to the ciliary processes, to the furrows between the ciliary processes, and to the ora serrata. Centrally, the fibres are attached to the lens, mostly in front, and a few behind the equator (Fig. 19.5).

DISSECTION

Give an incision in the anterior surface of lens and with a little pressure of fingers and thumb press the body of lens outside from the capsule.

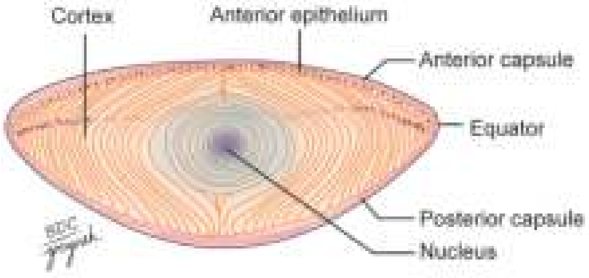

Cortex
Anterior epithelium
Anterior capsule
Equator
Posterior capsule
Nucleus

Fig. 19.8: The lens

Competency:
AN41.2 Describe the anatomical aspects of cataract, glaucoma and central retinal artery occlusion.

CLINICAL ANATOMY

- Lens becomes opaque with increasing age (***cataract***). Since the opacities cause difficulty in vision, lens has to be replaced.
- ***Presbyopia:*** With increasing age, crystalline lens loses its elasticity and power of accommodation for near vision (reading). These changes are more evident by the age of 40 to 45 years and the condition is called presbyopia. It can be corrected with convex lens.
- Left third nerve paralysis causes partial ptosis and dilated pupil. The cornea is turned downwards and outwards (Fig. 19.9).
- Horner's syndrome results in partial ptosis and miosis (Fig. 19.10).
- In brainstem death, both the pupils are dilated and fixed (Fig. 19.11).
- ***Fundoscopy*** (*fundoscopic examination*): It is a visualization of the retina and the interior of the eyeball using an *ophthalmoscope*. It is useful for examination of the posterior region of retina (fundus).
  Structures visualized (Figs 19.12a and b):
  - *Macula lutea*: It is a pale yellowish area near the posterior pole. It is approximately 4 mm in diameter.
  - *Fovea*: It is a small pit (1.5 mm in diameter) in centre of macula lutea. It is called fovea centralis, which is the point where light is normally focused.
  - The fovea is the portion of retina with maximum concentration of cone receptors, hence the site of the greatest visual acuity.
  - *Optic disc* (1.5 mm in diameter): It is a white spot about 3 mm medial to the macula. The nerve fibres from retina converge and pass through the optic disc of the eyeball to form the optic nerve. The blood vessels of retina also pass through the optic disc.
  - *Central artery of the retina*: It enters the eye through the centre of the optic disc. It divides into superior and inferior branches. Each of them further divides into temporal and nasal branches.

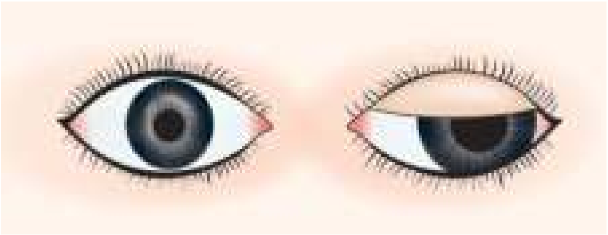


Fig. 19.9: Left third nerve paralysis

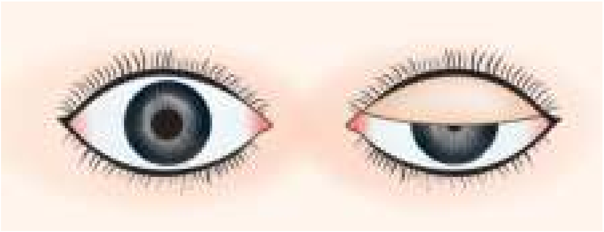


Fig. 19.10: Horner's syndrome in left eye

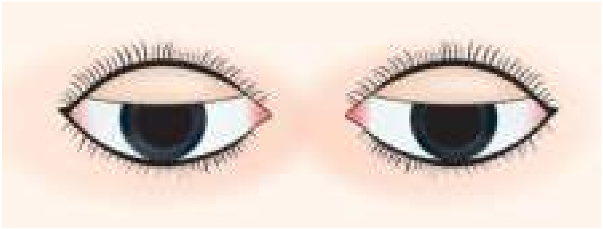
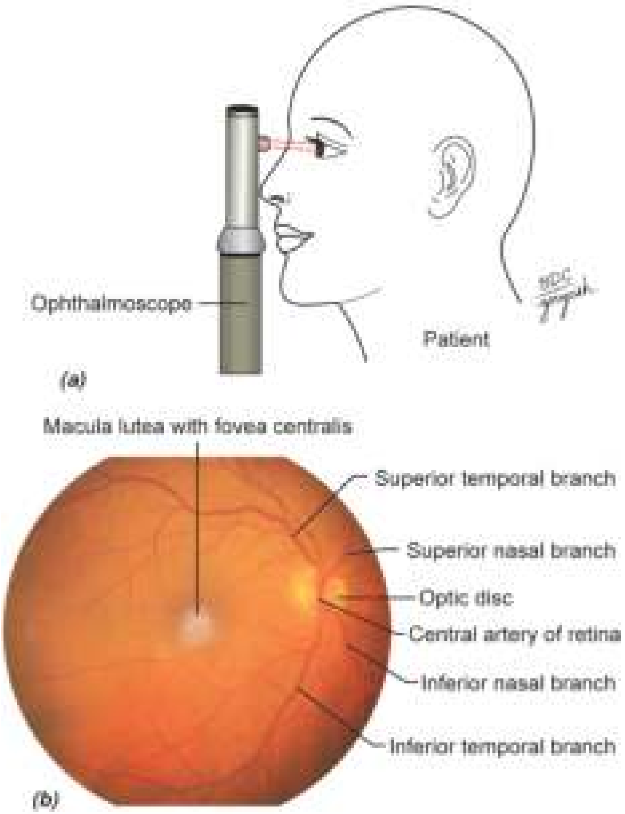


Fig. 19.11: Brainstem death


Ophthalmoscope
Patient
(a)
Macula lutea with fovea centralis
Superior temporal branch
Superior nasal branch
Optic disc
Central artery of retina
Inferior nasal branch
Inferior temporal branch
(b)

Figs 19.12a and b: (a) Procedure for ophthalmoscopy and (b) retina as seen by ophthalmoscope (*Image courtesy*: Dr Rohit Rao)

VITREOUS BODY

It is a colourless, jelly-like transparent mass which fills the posterior segment (posterior four-fifths) of the eyeball. It is enclosed in a delicate homogeneous ***hyaloid membrane***. Behind, it is attached to the optic disc, and in front to the ora serrata; in between it is free and lies in contact with the retina. The anterior surface of the vitreous body membrane is indented by the ciliary processes to form ciliary zonule.

Composition of vitreous body:

1. 99% water
2. Collagen, glycosaminoglycans (hyaluronan)
3. Hyalocytes – hyalocytes synthesize vitreous humour.

***Competency*:**

AN43.4 Describe the development and developmental basis of congenital anomalies of face, palate, tongue, branchial apparatus, pituitary gland, thyroid gland and eye.

DEVELOPMENT

Optic vesicle forms optic cup. It is an outpouching from the *forebrain* vesicle.

Lens from *lens placode (ectodermal)*

Retina—pigment layer from the *outer layer of optic cup;* nervous layers from the *inner layer of optic cup.*

Choroid, sclera—*mesoderm*

Cornea—*surface ectoderm forms the epithelium, other layers develop from mesoderm.*

VIDEO

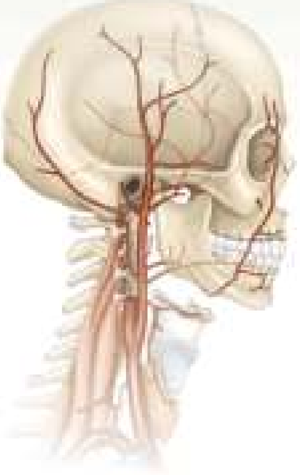
Video 3.19 Eyeball

Facts to Remember

- Cornea is used for grafting or transplantation.
- Tenon's capsule is a thin membranous sheath enclosing the eyeball
- Choroid contains big capillaries. These nourish the layer of rods and cones of retina by diffusion.
- Ciliary body contains ciliary muscles supplied by short ciliary nerves. These contract to relax the suspensory ligament of lens, so that the anterior surface of lens can become more convex for accommodation.
- Iris contains a weak dilator pupillae at the periphery, supplied by sympathetic fibres. It also contains a strong constricter or sphincter pupillae near the pupillary margin. This is supplied by parasympathetic fibres relayed through ciliary ganglion.
- Uvea (vascular coat) = choroid + ciliary body + iris.
- Canal of Schlemm is a circular vascular channel within sclera just behind the corneoscleral junction.
- Lamina cribrosa is the weakest site of sclera.
- Central artery of retina is an 'end artery'.
- Optic disc is the blind spot of the retina.
- Fundoscopy is a visualisation of the retina and the interior of the eyeball using an ophthalmoscope.

BDC's Anatomy *e*-book

1. Structures piercing the eyeball seen in a sagittal section
2. Differences between rod and cone cells
3. Molecular regulation of eye development
4. Further reading
5. Viva voce questions



Chapter

20

Surface Marking and Radiological Anatomy

Competency:

AN43.5 Demonstrate: (1) Testing of muscles of facial expression, extraocular muscles, muscles of mastication, (2) Palpation of carotid arteries, facial artery, superficial temporal artery, (3) Location of internal and external jugular veins, (4) Location of hyoid bone, thyroid cartilage and cricoid cartilage with their vertebral levels.

Surface anatomy is the study of outline of organs and important internal structures on the surface of body. The surface anatomy or ***living surface anatomy*** of head, neck and face is very essential in clinical practice. It is a useful guide for visual inspection, palpation (feeling of internal structures through skin), for determination of size, consistency, and borders of structures (such as parotid gland, lymph nodes, and so on), and surgical procedures. These landmarks include bony and soft tissue landmarks.

SURFACE LANDMARKS

1. *Supraorbital margin* lies beneath the upper margin of the eyebrow.
2. *Supraorbital notch* is palpable at the junction of the medial 1/3rd with the lateral 2/3rd of the supraorbital margin, except in those cases in which the notch is converted into a foramen.
3. *Superciliary arch* is a curved bony ridge situated immediately above the medial part of each supraorbital margin.
4. *Glabella* is the median elevation connecting the two superciliary arches and corresponds to the elevation between the two eyebrows.
5. *Nasion* is the point where the internasal and frontonasal sutures meet. It lies a little above the floor of the depression at the root of the nose, below the glabella.
6. *Chin* is an anterior median area just above the centre of the lower border of mandible.
7. *Lower border or base of the mandible* demarcates face from neck.
8. *Body of the U-shaped hyoid bone* can be felt in the median plane just below and behind the chin, at the junction of the neck with the floor of the mouth. On each side, the body of hyoid bone is continuous posteriorly with the *greater cornua* which is overlapped in its posterior part by the sternocleidomastoid muscle.
9. *Thyroid cartilage of the larynx* forms a sharp protuberance in the median plane just below the hyoid bone. This protuberance is called the *laryngeal prominence or Adam's apple.* It is more prominent in males than in females.
10. *Suprasternal notch* is present above the upper border of manubrium sterni in between the medial ends of clavicle. It lies at the level of lower border of T2 vertebra.
11. *Trachea* is commonly palpated in the *suprasternal notch*. In certain diseases, the trachea may shift to one side from the median plane. This indicates a shift in the mediastinum.
12. *Sternocleidomastoid muscle* becomes prominent when the face is turned to the opposite side.
13. *Lesser supraclavicular fossa* is a small triangular depression above the medial end of the clavicle between the sternal and clavicular heads of sternocleidomastoid muscle. The internal jugular vein lies deep to this fossa.
14. *Greater supraclavicular fossa* is a depression above the middle one-third of the clavicle. The cervical part of brachial plexus and the third part of the subclavian artery are situated deep to this fossa.
15. *External ear* or *pinna* is a prominent feature of the lateral aspect of the head (for details, *see* Chapter 18).
16. *Zygomatic bone* is a prominent bar at the inferolateral corner of the orbit. The *zygomatic arch* bridges the gap between the eye and the ear.
17. *Preauricular point* lies on the posterior root of the zygoma immediately in front of the upper part of the tragus.
18. *Head of the mandible* can be felt in front of the tragus, during movements of the lower jaw.
19. *Ramus of the mandible* can be felt through the skin. The outer surface of the ramus is covered by the masseter which becomes prominent when the teeth are clenched. The lower border of the mandible can be traced posteriorly into the *angle* of the mandible.

20. *Parietal eminence* is the most prominent part of the parietal bone, situated far above and a little behind the auricle.
21. *Mastoid process* is a large bony prominence situated behind the lower part of the auricle.
22. *Supramastoid crest* is about 2.5 cm long, begins immediately above the external acoustic meatus and soon curves upward and backward.
23. *Temporal line*: The upper margin of the contracted temporalis muscle demarcates the temporal line. This line extends from the zygomatic process of the frontal bone, arches posterosuperiorly across the coronal suture, passes a little below the parietal eminence, and turns downward to become continuous with the supramastoid crest. The area of the temporal fossa on the side of the head, above the zygomatic arch, is called the *temple* or temporal region.
24. *Pterion*: It is the area in the temporal fossa. It is the meeting point of four bones: Frontal, parietal, temporal and sphenoid. It is a H-shaped suture. *Surface marking*: The centre of the pterion is marked by a point 4 cm above the midpoint of the zygomatic arch, falling 3.5 cm behind the frontozygomatic suture.

    Note: Deep to the pterion lie the anterior branch of the middle meningeal artery, the middle meningeal vein, and deeper still the stem of the lateral sulcus of the cerebral hemisphere (at the Sylvian point) dividing into three rami. The pterion is a common site for trephining (making a hole in the skull) during operation.
25. *External occipital protuberance* is a median bony prominence at the junction of the back of the head with the neck.
26. *Superior nuchal lines* are indistinct curved ridges which extend from the external occipital protuberance to the mastoid processes.
27. *Inion* is the most prominent median point situated on the external occipital protuberance.
28. *Transverse process of the atlas vertebra* can be felt on deep pressure midway between the angle of the mandible and the mastoid process, immediately anteroinferior to the tip of the mastoid process.
29. The *4th cervical transverse process* is just palpable at the level of the upper border of the thyroid cartilage; and the *6th cervical transverse process* at the level of the cricoid cartilage.
30. The anterior tubercle of the *transverse process of the 6th cervical vertebra* is the largest of all such processes and is called the *carotid tubercle* (of Chassaignac). The common carotid artery can be best pressed against this tubercle, deep to the anterior border of the sternocleidomastoid muscle.

Note:

Other important landmarks

- *Frontozygomatic suture* can be felt as a slight depression in the upper part of the lateral orbital margin.
- *Marginal tubercle* lies a short distance below the frontozygomatic suture along the posterior border of the frontal process of the zygomatic bone.
- *Frankfurt's plane* is represented by a horizontal line joining the infraorbital margin to the centre of the external acoustic meatus. Posteriorly, the line passes through a point just below the external occipital protuberance.
- *Jugal point* is the anterior end of the upper border of the zygomatic arch where it meets the frontal process of the zygomatic bone.
- *Mandibular notch* is represented by a curved line concave upwards, extending from the head of the mandible to the anterior end of the zygomatic arch. The notch is 1–2 cm deep.

Competency:

AN43.6 Demonstrate surface projection of: Thyroid gland, parotid gland and duct, pterion, common carotid artery, internal jugular vein, subclavian vein, external jugular vein, facial artery in the face and accessory nerve.

SURFACE MARKING OF VARIOUS STRUCTURES

ARTERIES

Facial Artery

It is marked on the face by joining these three points (Fig. 20.1):

- Point 1: On the base of the mandible at the anterior border of the masseter muscle.
- Point 2: 1.2 cm lateral to the angle of the mouth.
- Point 3: At the medial angle of the eye.

The artery is tortuous in its course and is more so between the first two points (Fig. 20.1).

Common Carotid Artery

It is marked by a broadline along the anterior border of the sternocleidomastoid muscle by joining the following two points (Fig. 20.2):

- Point 1: On the sternoclavicular joint.
- Point 2: On the anterior border of the sternocleidomastoid muscle at the level of upper border of the thyroid cartilage (Fig. 20.2).

The thoracic part of the left common carotid artery is marked by a broadline extending from a point a little to the left of the centre of the manubrium to the left sternoclavicular joint.

Internal Carotid Artery

It is marked by a broadline joining these two points (Fig. 20.2).

- Point 2: On the anterior border of the sternocleidomastoid muscle at the level of the upper border of the thyroid cartilage.
- Point 3: On the posterior border of the condyle of the mandible.

External Carotid Artery

The artery is marked by joining these two points (Fig. 20.3).

- Point 2: On the anterior border of the sternocleidomastoid muscle at the level of the upper border of the thyroid cartilage.
- Point 4: On the posterior border of the neck of the mandible.

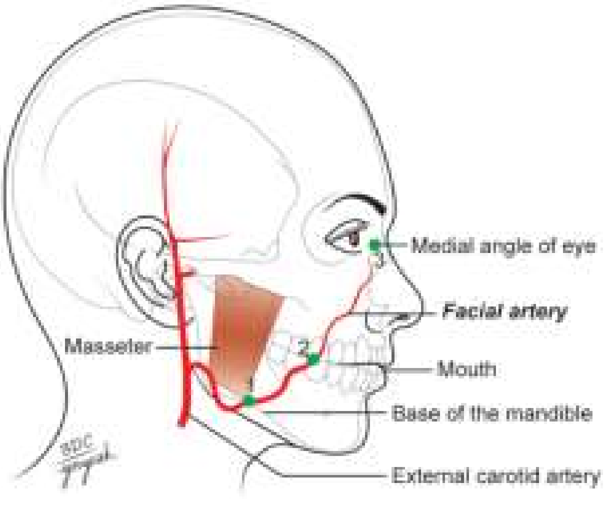

Medial angle of eye
3
Facial artery
1
Masseter
2
Mouth
Base of the mandible
External carotid artery

Fig. 20.1: Facial artery

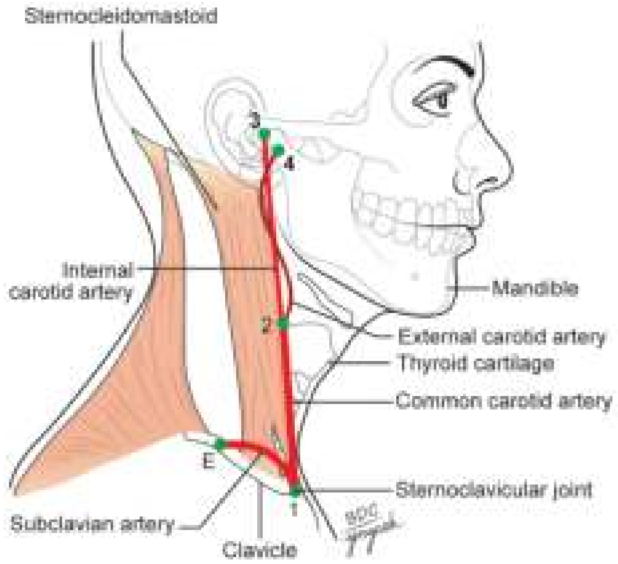

Sternocleidomastoid
3
4
Internal carotid artery
Mandible
2
External carotid artery
Thyroid cartilage
Common carotid artery
E
Sternoclavicular joint
1
Subclavian artery
Clavicle

Fig. 20.2: Surface marking of common, external and internal carotid arteries

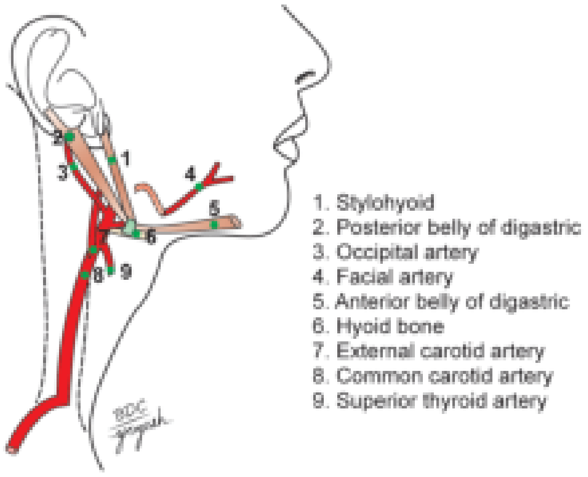

2
1
3
4
5
7
6
8
9
1. Stylohyoid
2. Posterior belly of digastric
3. Occipital artery
4. Facial artery
5. Anterior belly of digastric
6. Hyoid bone
7. External carotid artery
8. Common carotid artery
9. Superior thyroid artery

Fig. 20.3: Some branches of external carotid artery

The artery is slightly convex forwards in its lower half and slightly concave forwards in its upper half.

Branches of external carotid artery are shown in Fig. 20.3.

Subclavian Artery

It is marked by a broad curved line, convex upwards, by joining these two points (Fig. 20.2).

- Point 1: On the sternoclavicular joint.
- Point 5: At the middle of the lower border of the clavicle.

The artery rises about 2 cm above the clavicle.

The thoracic part of the left subclavian artery is marked by a broad vertical line along the left border of the manubrium a little to the left of the left common carotid artery.

Middle Meningeal Artery

It is marked by joining these points (Fig. 20.4):

- Point 1: Immediately above the middle of the zygoma. The artery enters the skull opposite this point.
- Point 2: 3 cm above the first point. The artery divides deep to this point.
- Point 3: At the centre of pterion, that is, 3.5 cm behind and 1.5 cm above the frontozygomatic suture.
- Point 4: Midway between the nasion and inion.
- Point 5: At the superior attachment of auricle.
- Point 6: At lambda, that is, 6 cm above the external occipital protuberance.

The line joining points 1 and 2 represents the stem of the middle meningeal artery inside the skull.

The line joining points 2, 3 and 4 represents the anterior (frontal) branch. It first runs upwards and forwards and then upwards and backwards, towards the point 4.

The line joining points 2, 5 and 6 represents the posterior (parietal) branch. It runs backwards and upwards, towards the point 5.

VEINS/SINUSES

External Jugular Vein

The vein is usually visible through the skin and can be made more prominent by blowing with the mouth and nostrils closed (Fig. 20.5).

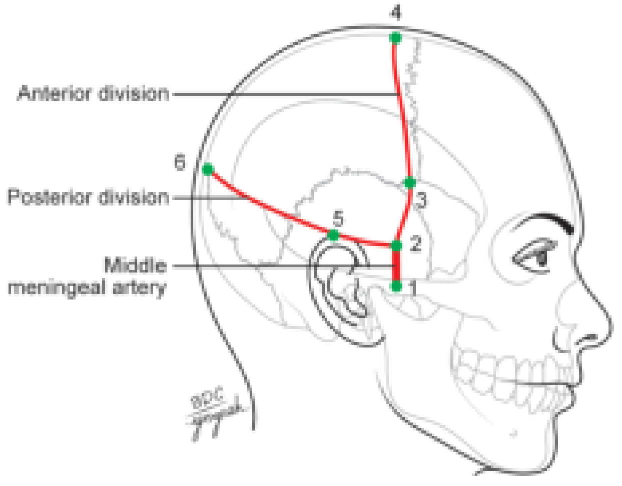

4
Anterior division
6
Posterior division
3
5
2
Middle meningeal artery
1

Fig. 20.4: Surface marking of middle meningeal artery

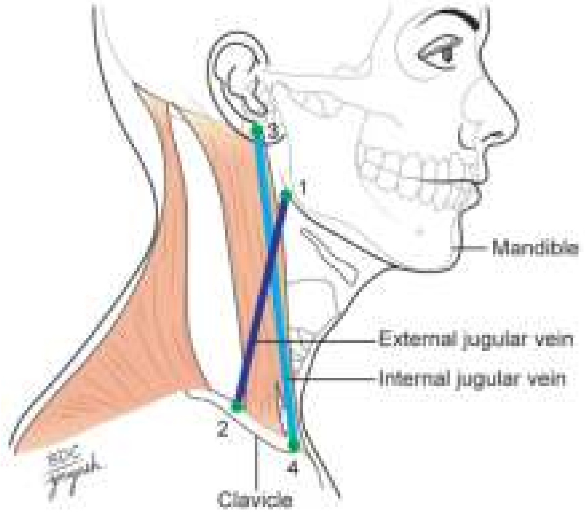


Fig. 20.5: Surface marking of internal and external jugular veins

It can be marked, if not visible, by joining these points:

- Point 1: A little below and behind the angle of the mandible.
- Point 2: On the clavicle just lateral to the posterior border of the sternocleidomastoid.

Internal Jugular Vein

Internal jugular vein is marked by a broadline by joining these two points (Fig. 20.5):

- Point 3: On the neck medial to the lobule of the ear.
- Point 4: At the medial end of the clavicle (Fig. 20.5).

The lower bulb of the vein lies beneath the lesser supraclavicular fossa between the sternal and clavicular heads of the sternocleidomastoid muscle.

Subclavian Vein

Subclavian vein is represented by a broadline along the clavicle extending from a little medial to its midpoint to the medial end of the bone (Fig. 20.2).

Superior Sagittal Sinus

Superior sagittal sinus is marked by two lines (diverging posteriorly) joining these two points (Fig. 20.6):

- Point A: At the glabella.
- Point B: At the inion, two dots situated side-by-side, 1.2 cm apart (Fig. 20.6).

Transverse Sinus

Transverse sinus is marked by two parallel lines, 1.2 cm apart extending between the following points (Fig. 20.6):

- Point B: Two dots, at the inion, situated one above the other and 1.2 cm apart.
- Point C: Two dots, at asterion 3.75 cm behind external auditory meatus and 1.25 cm above this point (Fig. 20.6).
- Point D: Two dots, at the base of the mastoid process, situated one in front of the other and 1.2 cm apart.

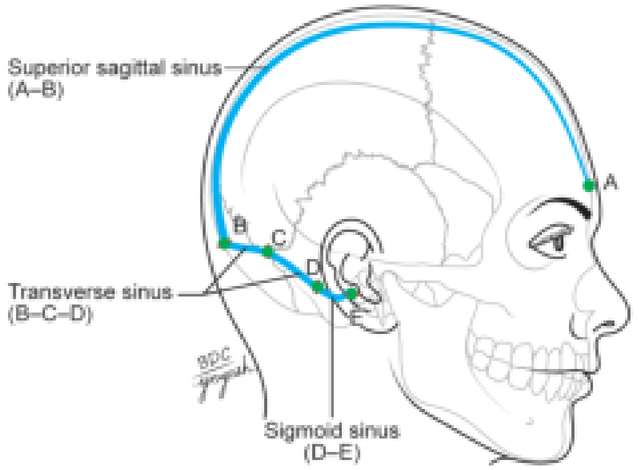


Fig. 20.6: Surface marking of superior, transverse, and sigmoid sinuses

Sigmoid Sinus

Sigmoid sinus is marked by two parallel lines situated 1.2 cm apart and extending between the following two points (Fig. 20.6):

- Point D: Two dots, at the base of the mastoid process, situated one in front of the other and 1.2 cm apart.
- Point E: Two similar dots, near the posterior border and 1.2 cm above the tip of mastoid process.

Veins of face and neck are shown in Fig. 20.7.

NERVES

Facial Nerve

Facial nerve is marked by a short horizontal line joining the following two points (Fig. 20.8):

- Point 1: At the middle of the anterior border of the mastoid process. The stylomastoid foramen lies 2 cm deep to this point.
- Point 2: Behind the neck of mandible. Here the nerve divides into its five branches to the facial muscles (Fig. 20.8).

Mandibular Nerve

Mandibular nerve (point 1 to point 2) is marked by a short vertical line (2 cm) in the posterior part of the mandibular notch just in front of the head of the mandible (Fig. 20.9).

Auriculotemporal Nerve

Auriculotemporal nerve is marked by a line drawn first backwards from the posterior part of the mandibular notch (point 2) (site of mandibular nerve) across the neck of the mandible, and then upwards across the preauricular point 3 (Fig. 20.9).

Lingual and Inferior Alveolar Nerves

Lingual nerve is marked by a curved line running downwards and forwards by joining these points (Fig. 20.9):

- Point 2: On the posterior part of the mandibular notch, in line with the mandibular nerve.

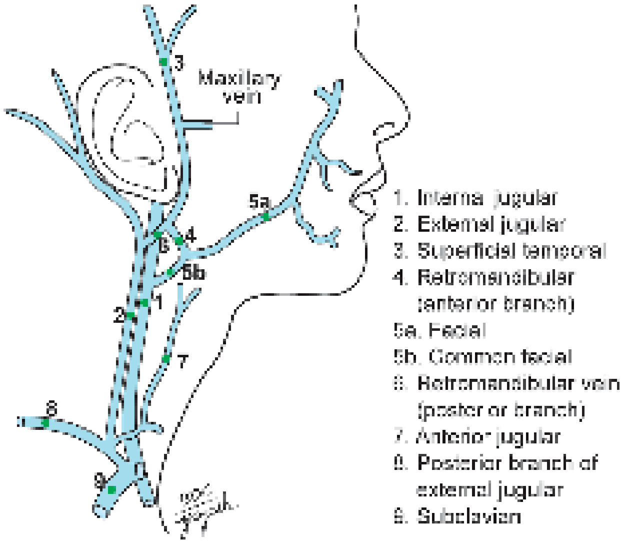

3
Maxillary vein
5a
6
4
5b
1
2
7
8
9
1. Internal jugular
2. External jugular
3. Superficial temporal
4. Retromandibular (anterior branch)
5a. Facial
5b. Common facial
6. Retromandibular vein (posterior branch)
7. Anterior jugular
8. Posterior branch of external jugular
9. Subclavian

Fig. 20.7: Veins of the face and neck

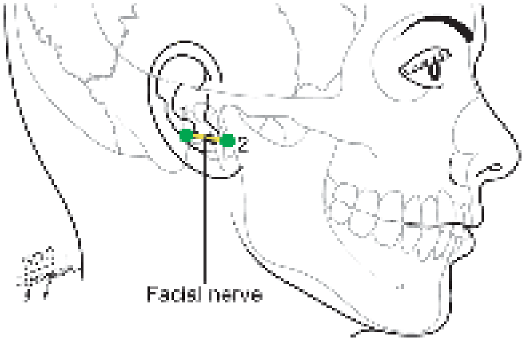

2
Facial nerve

Fig. 20.8: Surface marking of facial nerve

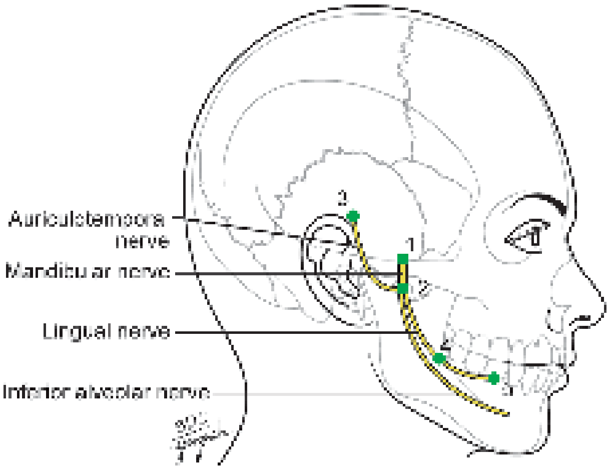

Auriculotemporal nerve
Mandibular nerve
Lingual nerve
Inferior alveolar nerve
3
1
2
4
5

Fig. 20.9: Surface marking of mandibular, auriculotemporal, lingual and inferior alveolar nerves

- Point 4: A little below and behind the last lower molar tooth.
- Point 5: Opposite the first lower molar tooth.

The concavity in the course of the nerve is more marked between the 4 and 5 points and is directed upwards.

Inferior alveolar nerve lies a little below and parallel to the lingual nerve.

Glossopharyngeal Nerve

Glossopharyngeal nerve is marked by joining the following points (Fig. 20.10):

- Point A: On the anteroinferior part of the tragus.
- Point B: Anterosuperior to the angle of the mandible.

From 2nd point, the nerve runs forwards for a short distance above the lower border of the mandible.

The nerve describes a gentle curve in its course (Fig. 20.10).

Vagus Nerve

The nerve runs along the medial side of the internal jugular vagus vein. It is marked by joining these two points (Fig. 20.10):

- Point A: At the anteroinferior part of the tragus.
- Point C: At the medial end of the clavicle (Fig. 20.10).

Accessory Nerve (Spinal Part)

Accessory nerve (spinal part) is marked by joining the following four points (Fig. 20.10):

- Point A: At the anteroinferior part of the tragus.
- Point D: At the tip of the transverse process of the atlas.
- Point E: At the middle of the posterior border of the sternocleidomastoid muscle.
- Point F: On the anterior border of the trapezius 6 cm above the clavicle.

Hypoglossal Nerve

Hypoglossal nerve is marked by joining these points (Fig. 20.10):

- Point A, at the anteroinferior part of the tragus.
- Point G, posterosuperior to the tip of the greater cornua of the hyoid bone.
- Point H, midway between the angle of the mandible and the symphysis menti.

The nerve describes a gentle curve in its course.

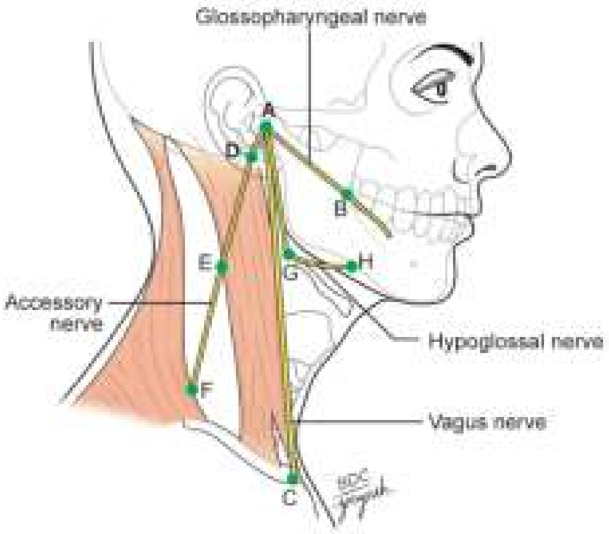

Glossopharyngeal nerve
A
D
B
E
G
H
Accessory nerve
Hypoglossal nerve
F
Vagus nerve
C

Fig. 20.10: Position of last four cranial nerves

Phrenic Nerve

Phrenic nerve is marked by a line joining the following points (Fig. 20.11):

- Point A: On the side of the neck at the level of the upper border of the thyroid cartilage and 3.5 cm from the median plane.
- Point B: At the medial end of the clavicle (Fig. 20.11).

Cervical Sympathetic Chain

Cervical sympathetic chain is marked by a line joining the following points (Fig. 20.11):

- Point C: At the sternoclavicular joint.
- Point D: At the posterior border of the condyle of the mandible.

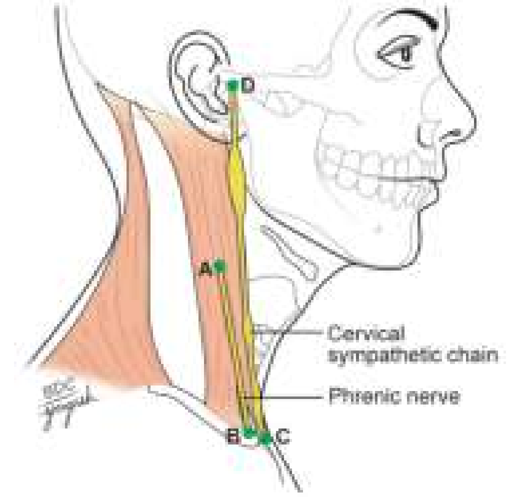


Fig. 20.11: Position of phrenic nerve and sympathetic trunk

GLANDS

Parotid Gland

Parotid gland is marked by joining these four points with each other (Fig. 20.12):

- Point A: At the upper border of the head of the mandible.
- Point B: Just above the centre of the masseter muscle.
- Point C: At the posteroinferior to the angle of the mandible.
- Point D: On the upper part of the anterior border of the mastoid process.

The anterior border of the gland is obtained by joining the points A, B, C; the posterior border, by joining the points C, D; and the superior curved border with its concavity directed upwards and backwards, by joining the points A, D across the lobule of the ear (Fig. 20.12).

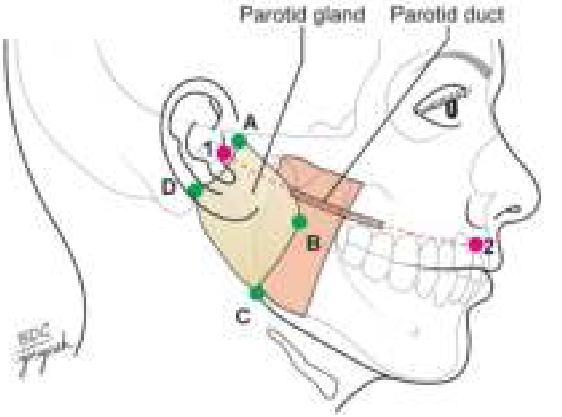


Fig. 20.12: Surface marking of parotid gland and parotid duct

Parotid Duct

To mark this duct, first draw a line joining the following two points (Fig. 20.12):

- Point 1: At the lower border of the tragus.
- Point 2: Midway between the ala of the nose and the red margin of the upper lip.

The middle-third of this line represents the parotid duct (Fig. 20.12).

Submandibular Gland

The submandibular salivary gland is marked by an oval area joining the following points (Fig. 20.13):

- Point A: A point below the angle of mandible.
- Point B: Midway between the angle of mandible and the symphysis menti.
- Point C: About 1.5 cm above the angle of mandible.
- Point D: Near the posterior end of the tip of the greater cornua of the hyoid bone.

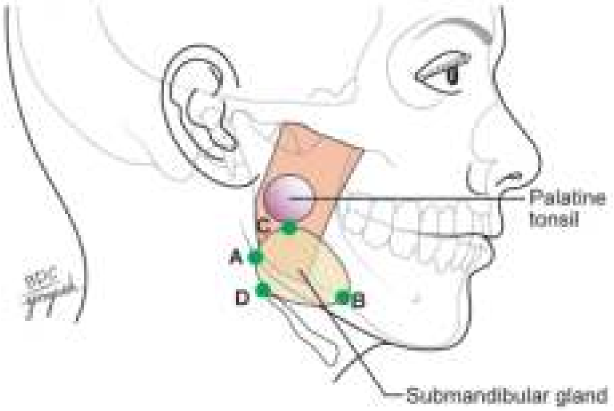


Fig. 20.13: Surface marking of submandibular gland and palatine tonsil

Thyroid Gland

The isthmus of thyroid gland is marked by two transverse parallel lines (each 1.2 cm long) on the trachea, the upper 1.2 cm and the lower 2.5 cm below the arch of the cricoid cartilage.

Each lobe extends up to the middle of the thyroid cartilage, below to the clavicle, and laterally to be overlapped by the anterior border of sternocleidomastoid muscle. The upper pole of the lobe is pointed, and the lower pole is broad and rounded (Fig. 20.14).

Palatine Tonsil

Palatine tonsil is marked by an oval (almond-shaped) area over the masseter just anterosuperior to the angle of the mandible.

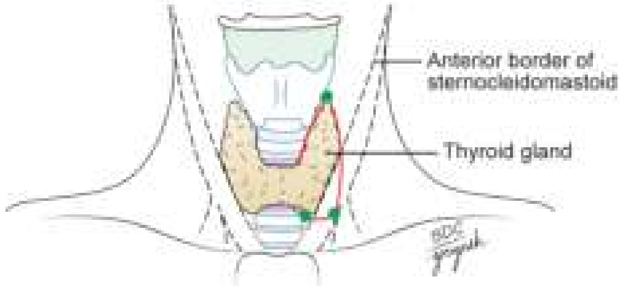


Fig. 20.14: Thyroid gland

PARANASAL SINUSES

Frontal Sinus

Frontal sinus is marked by a triangular area formed by joining these three points (Fig. 20.15):

- Point 1: At the nasion.
- Point 2: 2.5 cm above the nasion.
- Point 3: At the junction of medial one-third and lateral two-thirds of the supraorbital margin, i.e. at the supraorbital notch.

Maxillary Sinus

The roof of maxillary sinus is represented by the inferior orbital margin; the floor, by the alveolus of the maxilla; the base, by the lateral wall of the nose. The apex lies on the zygomatic process of the maxilla.

Competency:
AN43.7 Identify the anatomical structures in: (1) Plain X-ray skull; (2) AP view and lateral view, (3) Plain X-ray cervical spine—AP and lateral view, (4) Plain X-ray of paranasal sinuses.

RADIOLOGICAL ANATOMY

In routine clinical practice, the following X-ray pictures of the skull are commonly used.

1. Lateral view for general survey of the skull including cervical vertebrae.
2. A special posteroanterior view (in Water's position) to study the paranasal sinuses.

LATERAL VIEW OF SKULL (PLAIN SKIAGRAM)

In the lateral view of skull, one side of the head faces toward the radiographic film and other side to the X-ray tube.

For radiological examination, the skull should be observed for the features of (Fig. 20.16):

1. Cranial vault
2. Base of the skull.

Cranial Vault

Shape and size: It is important to be familiar with the normal shape and size of the skull so that abnormalities, like oxycephaly (a type of cranio-stenosis), hydrocephalus, microcephaly, etc. may be diagnosed.

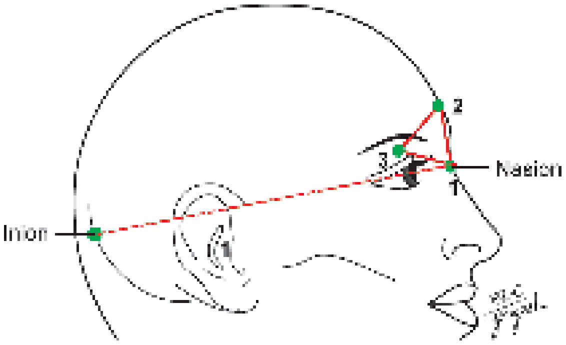


Fig. 20.15: Surface marking of frontal air sinus

Structure of cranial bones: The bones are unilamellar during the first three years of life. Two tables separated by diploe appear during the fourth year, and the differentiation reaches its maximum by about 35 years when diploic veins produce characteristic markings in radiograms. The sites of the external occipital protuberance and frontal bone are normally thicker than the rest of the skull. The squamous temporal and the upper part of the occipital bone are thin.

Generalized thickened bones are found in Paget's disease. Thalassaemia, a congenital haemolytic anaemia, is associated with thickening and a characteristic sunray appearance of the skull bones. A localised hyperostosis may be seen over a meningioma. In multiple myeloma and secondary carcinomatous deposits, the skull presents large punched out areas Fractures are more extensive in the inner table than in the outer table.

Sutures: The coronal and lambdoid sutures are usually visible clearly. The coronal suture runs downwards and forwards in front of the central sulcus of the brain. The lambdoid suture traverses the posteriormost part of the skull.

Obliteration of sutures begins first on the inner surface (between 30 and 40 years) and then on the outer surface (between 40 and 50 years). Usually, the lower part of the coronal suture is obliterated first, followed by the posterior part of the sagittal suture. Premature closure of sutures occurs in craniostenosis, a hereditary disease. Sutures are opened up in children by an increase in intracranial pressure.

Vascular markings

a. *Middle meningeal vessels:* The anterior branch runs about 1 cm behind the coronal suture. The posterior branch runs backwards and upwards at a lower level across the upper part of the shadow of the auricle.
b. The *transverse sinus* may be seen as a curved dark shadow, convex upwards, extending from the internal occipital protuberance to the petrous temporal.
c. The *diploic venous markings* are seen as irregularly anastomosing, worm-like shadows produced by the frontal, anterior temporal, posterior temporal and occipital diploic veins. These markings become more prominent in raised intracranial pressure.

Cerebral moulding: Indicating normal impressions of cerebral gyri, can be seen. In raised intracranial tension,

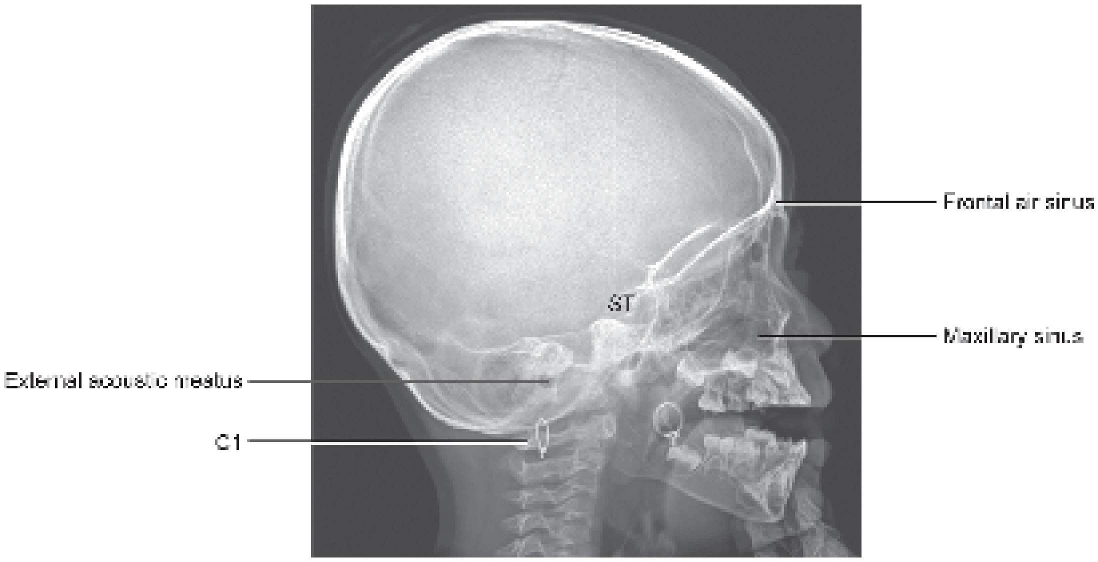


Fig. 20.16: Plane radiograph of skull: Lateral view (*Image courtesy*: Dr Janani Baradwaj)

the impressions become more pronounced and produce a characteristic *silver beaten* (or *copper beaten) appearance* of the skull.

Arachnoid granulations: They may indent the parasagittal area of the skull to such an extent as to simulate erosion by a meningioma.

Normal intracranial calcifications

a. Pineal concretions (brain sand) appear by the age of 17 years. The pineal body is located 2.5 cm above and 1.2 cm behind the external acoustic meatus. When visible it serves as an important radiological landmark.
b. Other structures which may become calcified include the choroid plexuses, arachnoid granulations, falx cerebri, and other dural folds.

Auricle: The curved margin of the auricle is seen above the petrous temporal.

Frontal sinus: It produces a dark shadow in the antero-inferior part of the skull vault.

Base of Skull

1. ***Floor of the anterior cranial fossa*** slopes backwards and downwards. The shadows of the two sides are often seen situated one above the other. The surface is irregular due to gyral markings. It also forms the roof of the orbit.
2. ***Hypophyseal fossa*** represents the middle cranial fossa in this view. It is overhung anteriorly by the anterior clinoid process (directed posteriorly), and posteriorly by the posterior clinoid process. It measures 8 mm vertically and 14 mm anteroposteriorly. The interclinoid distance is not more than 4 mm. The fossa is enlarged in cases of pituitary tumours, arising particularly from acidophil or chromophobe cells.
3. ***Sphenoidal air sinus*** lies anteroinferior to the hypophyseal fossa. The shadows of the orbit, the nasal cavities, and the ethmoidal and maxillary sinuses lie superimposed on one another, below the anterior cranial fossa.
4. ***Petrous part of the temporal bone*** produces a dense irregular shadow posteroinferior to the hypophyseal fossa. Within this shadow, there are two dark areas representing the external acoustic meatuses of the two sides; each shadow lies immediately behind the head of the mandible of that side. Similar dark shadows of the internal acoustic meatuses may also be seen. The posterior part of the dense shadow merges with the mastoid air cells producing a honeycomb appearance.
5. In addition to the features mentioned above, the *mandible* lies anteriorly forming the lower part of the facial skeleton. The *upper cervical vertebrae* lie posteriorly and are seen as a pillar supporting the skull.

ANTEROPOSTERIOR VIEW OF SKULL (PLAIN SKIAGRAM)

The skull anteroposterior (AP) view is a nonangled radiograph of the skull. This view provides an overview of the entire skull. In AP view, the back of patient's head is placed against the X-ray film.

Advantages of AP view: It gives overview of skull.

The disadvantages of AP view include:

- Overlap of bone makes it harder to evaluate the sinuses.
- Higher exposure of eyes to radiation than PA view.
- Higher magnification of the facial bones compared with the PA view.

Radiological features

The following features can be seen in the plain skiagram of skull in AP view:

1. Structure of cranial bones
2. Sutures: Lambdoid, metopic (if present)
3. Arachnoid granulations
4. Calcifications of pineal body, arachnoid granulations and so on
5. Shadow of auricle

6. Air sinuses: Frontal, other sinuses are overlapped by bones
7. Shadows of orbit and nasal cavities
8. Nasal septum
9. Mandible
10. Denture.

CERVICAL SPINE – ANTEROPOSTERIOR AND LATERAL VIEWS

The cervical vertebrae can be visualised better in lateral view with extended neck than in AP view.

Radiological features of the cervical spine

The following features of the cervical vertebrae are observed radiologically (Fig. 20.17):

1. Body of cervical vertebrae
2. Intervertebral space (discs)
3. Pedicles
4. Shadow of spines
5. Articular processes – superior and inferior
6. Intervertebral foramen.

WATER'S VIEW FOR PARANASAL SINUSES

The radiography for visualisation of paranasal air sinuses: Water's view is useful for radiological visualization of paranasal air sinuses.

Procedure: It is a special PA view of the skull taken with the head extended in such a way that the chin rests against the film with open mouth and the nose is raised from it (Water's position).

Features (Fig. 20.18)

1. *Frontal sinuses*: These are seen clearly. They are located immediately above the nose and medial parts of the orbits.
2. *Maxillary sinuses*: These are also seen clearly below the orbit, on each side of nasal cavity.
3. Ethmoid and sphenoid sinuses are also visible.
4. *Sinusitis*: If a sinus is infected, the shadow is either hazy or radio-opaque.

Competencies:

AN43.8 Describe the anatomical route used for carotid angiogram and vertebral angiogram.

AN43.9 Identify anatomical structures in carotid angiogram and vertebral angiogram.

Carotid Angiogram

Carotid angiogram lateral view. A radio-opaque dye was injected into the carotid artery just before the radiograph was taken (Fig. 20.19). Internal carotid artery is seen to give an ophthalmic branch and then ends by dividing into a smaller anterior cerebral and a larger middle cerebral arteries.

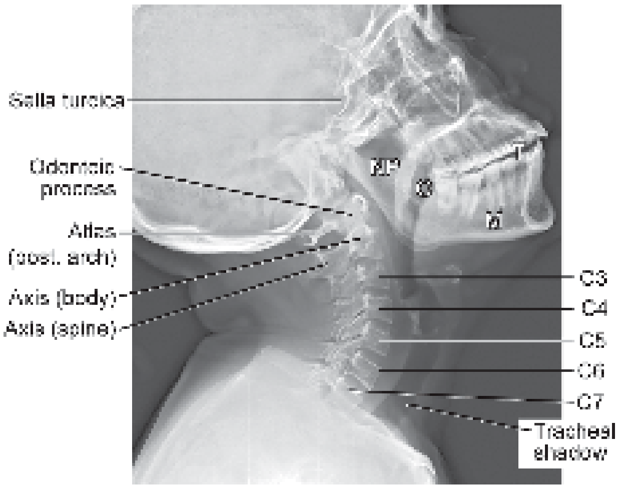

Sella turcica
Odontoid process
Atlas (post. arch)
Axis (body)
Axis (spine)
NP
O
M
T
C3
C4
C5
C6
C7
Tracheal shadow

Fig. 20.17: Lateral view of plain radiograph of cervical spine in extended neck position (M: Mandible, T: Teeth, O: Air shadow in oropharynx, NP: Air shadow in nasopharynx, *Image courtesy*: Dr Janani Baradwaj)

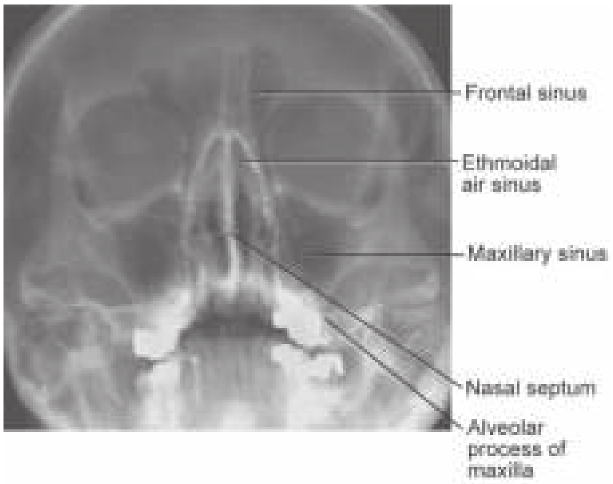

Frontal sinus
Ethmoidal air sinus
Maxillary sinus
Nasal septum
Alveolar process of maxilla

Fig. 20.18: X-ray of skull showing paranasal sinuses (Water's view/occipitomental view)

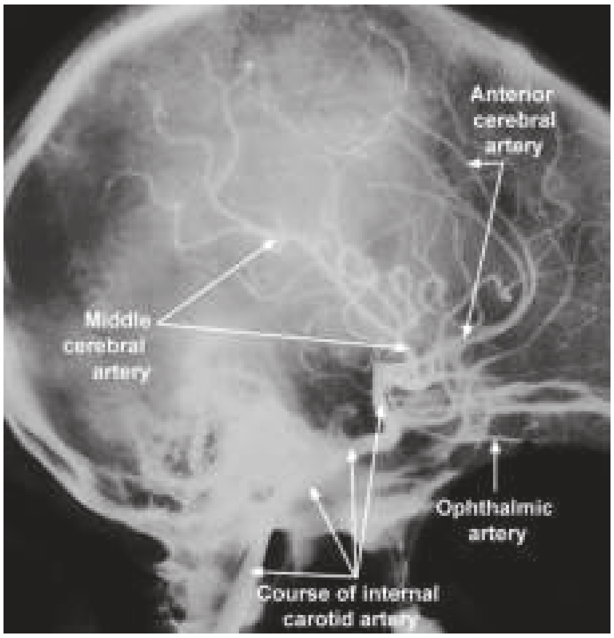

Anterior cerebral artery
Middle cerebral artery
Ophthalmic artery
Course of internal carotid artery

Fig. 20.19: Carotid angiogram

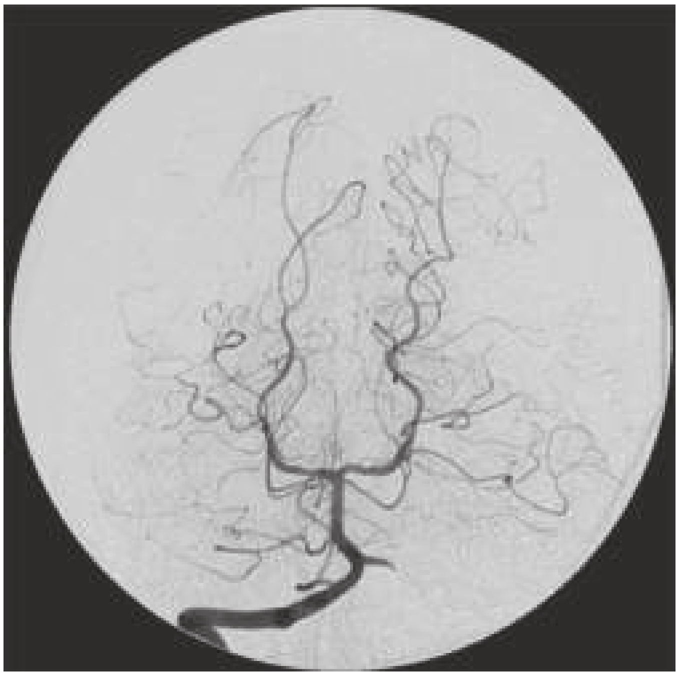


Fig. 20.20: Vertebral angiogram

Vertebral Angiogram

A vertebral angiogram or vertebral artery angiography is used to visualize the vertebral arteries (Fig. 20.20). For the vertebral angiogram, a contrast dye is injected through the catheter, making the blood vessels visible on X-ray images. X-ray images or fluoroscopy images are captured to assess the flow of blood with injected dye through the vertebral arteries. It is useful to detect abnormalities like blockages, aneurysms, arteriovenous malformations, or other vascular disorders affecting the vertebral arteries.

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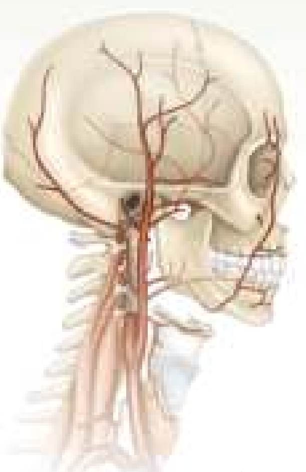
1. Further reading



Appendix

Parasympathetic Ganglia, Arteries and Pharyngeal Arches

CERVICAL PLEXUS

Ventral rami of C1–C4 form the cervical plexus. C1 runs along hypoglossal and supplies geniohyoid and thyrohyoid. It also gives superior limb of ansa cervicalis, which supplies superior belly of omohyoid and joins with inferior limb to form ansa. Inferior limb of ansa cervicalis is formed by ventral rami of C2, C3. Branches from ansa supply sternohyoid, sternothyroid, and inferior belly of omohyoid. Cervical plexus also gives four cutaneous branches—lesser occipital (C2), great auricular (C2, C3), supraclavicular (C3, C4) and transverse or anterior nerve of neck (C2, C3).

PHRENIC NERVE

Phrenic nerve arises primarily from ventral rami of C4 with small contributions from C3 and C5 nerve roots or through nerve to subclavius.

It is the only motor supply to its own half of diaphragm and sensory to mediastinal pleura, peritoneum and fibrous pericardium. Inflammation of peritoneum under diaphragm causes referred pain in the area of supraclavicular nerves supply, especially tip of the shoulders as their root value is also ventral rami of C3 and C4 (*see* Fig. 9.11).

SYMPATHETIC TRUNK

Branches of cervical sympathetic ganglia of sympathetic trunk are given in Table A.1 (For details, *see* Chapter 8).

PARASYMPATHETIC GANGLIA (Table A.2)

SUBMANDIBULAR GANGLION

Location

The submandibular ganglion lies superficial to hyoglossus muscle in the submandibular region. Functionally, submandibular ganglion is connected to facial nerve, while topographically it is connected to lingual branch of mandibular nerve (*see* Fig. 7.14).

Roots

The ganglion has sensory, sympathetic and secretomotor or parasympathetic roots.

1. Sensory root is from the lingual nerve. It is suspended by two roots of lingual nerve.
2. Sympathetic root is from the sympathetic plexus around the facial artery. This plexus contains postganglionic fibres from the superior cervical ganglion of sympathetic trunk. These fibres pass through the ganglion and are vasomotor to the gland.

TABLE A.1: Branches of cervical sympathetic ganglia

	Superior cervical ganglion	*Middle cervical ganglion*	*Inferior cervical ganglion*
Arterial branches	i. Along internal carotid artery as internal carotid nerve which gives deep petrosal, nerve to Muller's muscle, to dilator pupillae, to pineal gland ii. Along common carotid and external carotid arteries for all 3 salivary glands	Along inferior thyroid artery	Along subclavian and vertebral arteries
Grey rami communicantes	Along 1–4 cervical nerves	Along 5 and 6 cervical nerves	Along 7 and 8 cervical nerves
Along cranial nerves	Along cranial nerves IX, X, XI and XII	—	—
Visceral branches	Pharynx, cardiac	Thyroid, cardiac	Cardiac

TABLE A.2: Connections of parasympathetic ganglia

[*Note*: The sympathetic fibres arises from T1 spinal segment → Superior cervical ganglion → relay → postganglionic fibres form plexus around arteries]

Ganglia	***Sensory root***	***Sympathetic root***	***Secretomotor root/ parasympathetic root***	***Motor root***	***Distribution***
Submandibular	Two branches from lingual nerve	Branch from plexus around facial artery	Superior salivatory nucleus → facial nerve → chorda tympani (joins the lingual nerve) → relay in ganglion	— —	a. Submandibular b. Sublingual c. Anterior lingual glands
Pterygopalatine	Two branches from maxillary nerve	Deep petrosal from plexus around internal carotid artery	Superior salivatory nucleus, and lacrimatory nucleus → nervus intermedius → facial nerve → geniculate ganglion → greater petrosal nerve + deep petrosal nerve = nerve pterygoid canal	—	a. Mucous glands of nose, paranasal sinuses, palate, nasopharynx b. Some fibres pass through zygomatic nerve → zygomaticotemporal nerve → communicating branch to lacrimal nerve → lacrimal gland and tensor tympani
Otic	Branch from auriculotemporal nerve	Plexus along middle meningeal artery	Inferior salivatory nucleus → glossopharyngeal nerve → tympanic branch → nerve tympanic plexus → lesser petrosal nerve.	Branch from nerve to medial pterygoid	a. Secretomotor to parotid gland via auriculotemporal nerve b. Tensor veli palatini via nerve to med. pterygoid (unrelayed)
Ciliary	From nasociliary nerve	Plexus along ophthalmic artery	Edinger-Westphal nucleus → oculomotor nerve → nerve to inferior oblique	—	a. Ciliaris muscles b. Sphincter pupillae

3. Secretomotor root is from superior salivatory nucleus through nervus intermedius via chorda tympani which is a branch of cranial nerve VII. Chorda tympani joins lingual nerve. The parasympathetic fibres get relayed in the submandibular ganglion.

Branches

The ganglion gives direct branches to the submandibular salivary gland.

Some postganglionic fibres reach the lingual nerve to be distributed to sublingual salivary gland and glands in the oral cavity.

PTERYGOPALATINE GANGLION

Location

Pterygopalatine or sphenopalatine is the largest parasympathetic ganglion, suspended by two roots of maxillary nerve. Functionally, it is related to cranial nerve VII. It is called the ganglion of 'hay fever'.

Roots

The ganglion has sensory, sympathetic and secretomotor or parasympathetic roots.

1. Sensory root is from maxillary nerve. The ganglion is suspended by 2 roots of maxillary nerve.
2. Sympathetic root is from postganglionic plexus around internal carotid artery. The nerve is called deep petrosal. It unites with greater petrosal to form the nerve of pterygoid canal. The fibres of deep petrosal do not relay in the ganglion.
3. Secretomotor or parasympathetic root is from greater petrosal nerve which arises from geniculate ganglion of cranial nerve VII. These fibres relay in the ganglion.

Branches

The ganglion gives number of branches. These are:

1. *For lacrimal gland:* The postganglionic fibres pass through zygomatic branch of maxillary nerve. These fibres hitch hike through zygomaticotemporal nerve into the communicating branch between zygomaticotemporal and lacrimal nerves, then to the lacrimal nerve for supplying the lacrimal gland.
2. *Nasopalatine nerve:* This nerve runs on the nasal septum and ends in the anterior part of hard palate. It supplies secretomotor fibres to both nasal and palatal glands.
3. *Nasal branches:* These are medial posterior superior branches for the supply of glands and mucous membrane of nasal septum; the largest is named nasopalatine; and lateral posterior superior branches for the supply of glands and mucous membrane of lateral wall of nasal cavity.
4. *Palatine branches:* These are one greater/anterior palatine and 2–3 lesser/posterior palatine branches. These pass through the respective foramina to supply sensory and secretomotor fibres to mucous membrane and glands of soft palate and hard palate.

5. *Orbital branches* for the orbital periosteum.
6. *Pharyngeal branches* for the glands of pharynx.

OTIC GANGLION

Location

The otic ganglion lies deep to the trunk of mandibular nerve, between the nerve and the tensor veli palatini muscle in the infratemporal fossa, just distal to the foramen ovale. Topographically, it is connected to mandibular nerve, while functionally it is related to cranial nerve IX.

Roots

This ganglion has sensory, sympathetic, parasympathetic or secretomotor and motor roots (*see* Fig. 6.21).

1. Sensory root is by the auriculotemporal nerve.
2. Sympathetic root is by the sympathetic plexus around middle meningeal artery.
3. Secretomotor root is by the lesser petrosal nerve from the tympanic plexus formed by tympanic branch of cranial nerve IX. Fibres of lesser petrosal nerve relay in the otic ganglion. Postganglionic fibres reach the parotid gland through auriculotemporal nerve.
4. Motor root is by a branch from nerve to medial pterygoid. This branch passes unrelayed through the ganglion and divides into two branches to supply tensor veli palatini and tensor tympani

Branches

The postganglionic branches of the ganglion pass through auriculotemporal nerve to supply the parotid gland.

The motor branches supply the two muscles—tensor veli palatini and tensor tympani.

CILIARY GANGLION

Location

The ciliary ganglion is very small ganglion present in the orbit. Topographically, the ganglion is related to nasociliary nerve, branch of ophthalmic division of trigeminal nerve, but functionally it is related to oculomotor nerve. This ganglion gets parasympathetic fibres.

Roots

It has three roots—the sensory, sympathetic and parasympathetic. Only the parasympathetic root fibres relay to supply the intraocular muscles.

1. Sensory root is from the long ciliary nerve.
2. Sympathetic root is by the long ciliary nerve from plexus around ophthalmic artery.
3. Parasympathetic root is from a branch to inferior oblique muscle. These fibres arise from Edinger-Westphal nucleus, join oculomotor nerve and leave it via the nerve to inferior oblique, to be relayed in the ciliary ganglion.

Branches

The ganglion gives 10–12 short ciliary nerves. These contain postganglionic fibres for the supply of constrictor or sphincter pupillae for narrowing the size of pupil and ciliaris muscle for increasing the curvature of anterior surface of lens. These are required during accommodation of the eye.

ARTERIES OF HEAD AND NECK (Table A.3)

TABLE A.3: Common carotid artery

Artery	*Beginning, course and termination*	*Branches*
Common carotid (Table A.3)	It is a branch of brachiocephalic trunk on right side and a direct branch of arch of aorta on the left side. The artery runs upwards along medial border of sternocleidomastoid muscle enclosed within the carotid sheath. The artery ends by dividing into internal carotid and external carotid at the upper border of thyroid cartilage (*see* Fig. 4.13)	Two terminal branches: Internal carotid and external carotid
Internal carotid	It is a terminal branch of common carotid artery. It first runs through the neck (cervical part), then passes through the petrous bone (petrous part), then courses through the sinus (cavernous part) and lastly lies in relation to the brain (cerebral part)	***Cervical part:*** No branch ***Petrous part*** 1. Caroticotympanic branches 2. Pterygoid branch ***Cavernous part*** 1. Cavernous branches 2. Superior and inferior hypophyseal arteries. ***Cerebral part*** 1. Ophthalmic artery 2. Anterior choroidal artery 3. Posterior communicating artery 4. Anterior cerebral artery 5. Middle cerebral artery

(Contd.)

TABLE A.3: Common carotid artery *(Contd.)*

Artery	*Beginning, course and termination*	*Branches*
External carotid	It is one of the terminal branches of common carotid artery and lies anterior to internal carotid artery. External carotid artery starts at the level of upper border of thyroid cartilage, runs upwards and laterally to terminate behind the neck of mandible by dividing into larger maxillary and smaller superficial temporal branches	1. Ascending pharyngeal artery 2. Superior thyroid artery 3. Lingual artery 4. Facial artery 5. Occipital artery 6. Posterior auricular artery 7. Superficial temporal artery 8. Maxillary artery
Superior thyroid	It arises from anterior aspect of external carotid artery close to its origin. It runs downwards and forwards deep to the infrahyoid muscles to the upper pole of thyroid gland	1. Infrahyoid branch 2. Superior laryngeal artery 3. Cricothyroid branch 4. Sternocleidomastoid branch 5. Anterior and posterior branches
Lingual	It arises from anterior aspect of external carotid artery forms a typical loop which is crossed by XII nerve. Its 2nd part lies deep to the hyoglossus. The 3rd part runs along the anterior border of hyoglossus and 4th part runs forwards on the under surface of tongue	1. Suprahyoid artery 2. Dorsal lingual artery (3–4 in number) 3. Sublingual artery
Facial	This tortuous artery from anterior side also arises a little higher than lingual artery. It runs in the neck as cervical part and in the face as facial artery	1. Ascending palatine artery 2. Tonsillar artery 3. Glandular branches for submandibular gland 4. Submental artery 5. Inferior labial artery 6. Superior labial artery 7. Lateral nasal artery
Occipital	It arises from the posterior aspect of external carotid artery and runs upwards along the lower border of posterior belly of digastric muscle. Then it runs deep to mastoid process and the muscles attached to it. The artery then crosses the apex of suboccipital triangle and then it pierces trapezius 2.5 cm from midline to supply the layers of scalp (*see* Fig. 4.13)	1. Sternomastoid branches: Upper and lower 2. Mastoid branch 3. Meningeal branches 4. Muscular branches 5. Descending branch: Superficial and deep 6. Occipital branches
Posterior auricular	It arises from posterior aspect of external carotid artery, it runs along the upper border of posterior belly of digastric muscle to reach the back of auricle	1. Stylomastoid branch 2. Auricular branch 3. Occipital branch
Ascending pharyngeal	It arises from the medial side of external carotid artery, close to its origin. It runs upwards and between pharynx and tonsil on medial side and medial wall of middle ear on the lateral side (*see* Fig. 4.13)	1. Pharyngeal branches 2. Inferior tympanic branch 3. Meningeal branches
Superficial temporal	It is the smaller terminal branch of external carotid artery. It begins behind the neck of the mandible, runs upwards and crosses the preauricular point, where its pulsations can be felt. 5 cm above the preauricular point it ends by dividing into anterior and posterior branches (*see* Fig. 2.7)	1. Transverse facial artery 2. Anterior auricular branch 3. Zygomatico-orbital branch 4. Middle temporal artery 5. Anterior and posterior divisions
Maxillary	It is the larger terminal branch of external carotid artery. It is given off behind the neck of the mandible. Its course is divided into 1st, 2nd and 3rd parts according to its relations with lateral pterygoid muscle. 1st part lies below the lateral pterygoid, 2nd part lies on the lower head of lateral pterygoid and 3rd part lies between the two heads	***From the first part*** 1. Deep auricular 2. Anterior tympanic 3. Middle meningeal 4. Accessory meningeal 5. Inferior alveolar ***From the second part*** 1. Masseteric 2. Deep temporal 3. Pterygoid 4. Buccal

(Contd.)

TABLE A.3: Common carotid artery (*Contd.*)

Artery	*Beginning, course and termination*	*Branches*
		From third part 1. Posterior superior alveolar 2. Infraorbital 3. Greater palatine 4. Pharyngeal 5. Artery to pterygoid canal 6. Sphenopalatine
Subclavian artery	It is the chief artery of the upper limb. It also supplies part of neck and brain. On the right side, subclavian artery is a branch of the brachiocephalic trunk. On the left side, it is a direct branch of arch of aorta. The artery on either side ascends and enters the neck posterior to the sternoclavicular joint. The arteries of two sides have similar course. The artery arches from the sternoclavicular joint to the outer border of the first rib where it continues as the axillary artery. It is divided into three parts by the crossing of scalenus anterior muscle (*see* Figs 8.20 and 8.21)	***From 1st part*** 1. Vertebral artery 2. Internal thoracic artery 3. Thyrocervical trunk a. Inferior thyroid artery b. Transverse cervical artery c. Suprascapular artery 4. Costocervical trunk (only on the left side) a. Superior intercostal artery b. Deep cervical artery ***From 2nd part*** Costocervical trunk only on the right side ***From 3rd part*** Dorsal scapular artery (occasional branch; if present, it replaces the deep branch of transverse cervical artery)

PHARYNGEAL APPARATUS (Table A.4 to A.6)

TABLE A.4: Structures derived from skeletal and muscular components of pharyngeal arches (*Source*: Textbook of Human Embryology, Yogesh Sontakke, 2e, CBS Publishers)

Pharyngeal arch	*Muscles*	*Nerve*	*Skeletal elements*	*Ligament*
First arch (Meckel's cartilage)	Muscles of mastication (temporalis, masseter, medial and lateral pterygoid) Tensor veli palatini Tensor tympani Anterior belly of digastric Mylohyoid	Pretrematic: Chorda tympani Post-trematic: Mandibular nerve	Premaxilla Maxilla Zygomatic bone Temporal bone Incus Malleus	Anterior ligament of malleus Sphenomandibular ligament
Second arch (Reichert's cartilage)	Muscles of facial expression Posterior belly of digastric Stylohyoid Stapedius	Facial nerve	Stapes Styloid process Short (lesser) cornua of hyoid bone Superior part of body of hyoid bone	Stylohyoid ligament
Third arch	Stylopharyngeus	Glossopharyngeal nerve	Greater cornua of hyoid bone Lower part of body of hyoid bone	
Fourth arch	Cricothyroid, constrictors of pharynx, muscles of palate except tensor veli palatini	Superior laryngeal nerve	Laryngeal cartilages except epiglottis	
Sixth arch	Intrinsic muscles of larynx except cricothyroid	Recurrent laryngeal nerve		

TABLE A.5: Derivatives of ectodermal clefts

Pharyngeal cleft	*Derivatives*
Dorsal part of first ectodermal cleft	Epithelium of external auditory meatus
Auricle	Six auricular hillocks; three from first arch and three from II arch
Rest of ectodermal clefts	Obliterated by the overgrowth of second pharyngeal arch. The closing membrane of the first cleft is the tympanic membrane

TABLE A.6: Derivatives of endodermal pouches

Pharyngeal pouch	***Derivatives***
Dorsal ends of first and second pouches form tubotympanic recess	Proximal part of tubotympanic recess gives rise to auditory tube Distal part gives rise to tympanic cavity and mastoid antrum Mastoid cells develop at about 2 years of age
Ventral part of second pouch	Epithelium covering the palatine tonsil and tonsillar crypts Lymphoid tissue is mesodermal in origin
Third pouch	Thymus and inferior parathyroid gland or parathyroid III Thymic epithelial reticular cells and Hassall's corpuscles are endodermal Lymphocytes are derived from haemopoietic stem cells during 12th week
Fourth pouch	Superior parathyroid or parathyroid IV
Caudal pharyngeal complex	Thymic element – part of thymus Lateral thyroid element – part of thyroid gland Ultimobranchial body – parafollicular

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1. Molecular regulation of pharyngeal arches
2. Clinical terms

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BD Chaurasia's

Human Anatomy

Regional and Applied | Dissection and Clinical

Volume 1 UPPER LIMB and THORAX
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Volume
3

Widely acclaimed as a standard textbook in view of its simple language, comprehensive coverage, lucid presentation and neatly drawn line diagrams, BD Chaurasia's *Human Anatomy* remains the most preferred textbook in India and abroad. This edition has been thoroughly revised and updated to make it extremely student-friendly.

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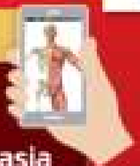

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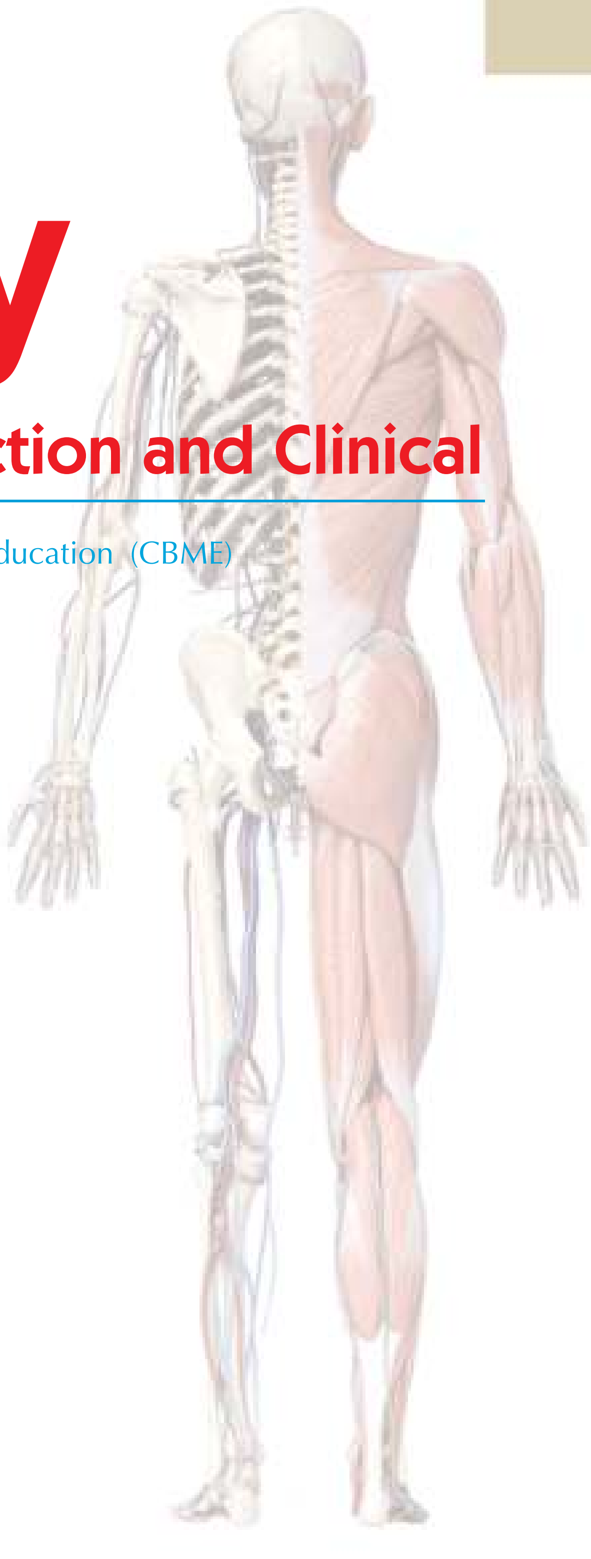

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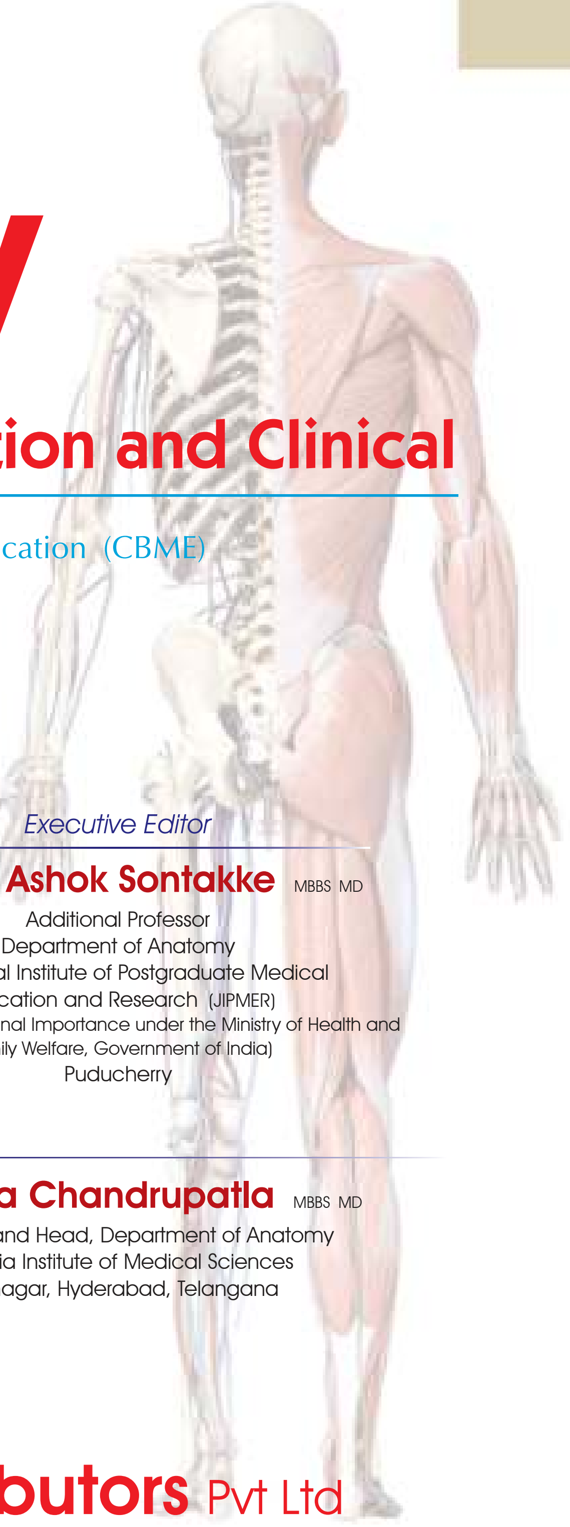

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Brain–Neuroanatomy

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Volume 1 **UPPER LIMB** and **THORAX**

LOWER LIMB, ABDOMEN and **PELVIS** Volume 2

Volume 3 **HEAD** and **NECK**

BRAIN–NEUROANATOMY Volume 4

Preface to the Tenth Edition

With the change in time, the needs of the students and curriculum are continuously changing. The science is continuously evolving. To integrate the solutions to common problems faced by the students and to follow the latest NMC guidelines for the CBME curriculum, the most widely accepted and read book has been revised thoroughly to maintain the standards of the last half-century. The primary goal of this book is to help the students for easy understanding and rapid grasping of knowledge for their higher academic achievements, to prepare them for all academic formative, summative and entrance examinations and to make it extremely student-friendly.

Anatomy forms the foundation of the clinical knowledge. This book has been made more clinically oriented with the following salient features:

- **Complete** and **time-tested textbook** boasting unparalleled **quality content** designed to enrich both fundamental and clinical understanding for students.
- **Simple text** is the main feature of the book. It will facilitate easier understanding for students. Small sentences minimize effort, enhancing readability and accessibility. This approach ensures clarity of information, aiding students in grasping complex concepts effortlessly.
- **3D colour illustrated plates** will aid the students in comprehending anatomical structures and their relationships with clarity. These visual aids offer a dynamic perspective, enhancing spatial understanding and facilitating the identification of anatomical features.
- **Simple line diagrams** are incorporated. These diagrams will allow students to easily redraw them during examinations. These diagrams are designed for clarity and simplicity, ensuring that students can accurately reproduce anatomical structures in assessments and examinations efficiently.
- **Flowcharts** will facilitate rapid revision and memorizing of facts, alleviating students' concerns about time constraints during the subject review. These visuals will enhance comprehension and retention. Students can quickly navigate through key concepts, optimizing study time and effectively addressing time limitations in their revision process.
- **Clinical anatomy** sections are integrated at the end of each topic to maintain the purpose towards **early clinical exposure** (ECE). By seamlessly merging theoretical knowledge with practical application, this approach ensures students gain valuable insights into clinical contexts, enhancing their understanding and readiness for real-world clinical scenarios.
- **Dissection boxes** will guide the students in the step-wise dissection of the human cadaver.
- **Tables** are used to summarise essential facts for clear understanding and retention.
- *QR codes* for ***eSmartQuiz*** are embedded in the text, which will grant access to online MCQ tests for self-assessment at the end of each chapter. This interactive feature will enhance engagement and facilitate convenient self-evaluation. Students can assess their understanding, reinforce learning, and identify areas for improvement, facilitate a dynamic and effective learning experience.
- ***Free Workbook:*** The main textbook is supported with a workbook, which has the following:
  1. **Clinicoanatomical problems** emphasize early clinical exposure and vertical integration in medical education. By integrating anatomical knowledge with clinical practice from the outset, students gain a holistic understanding of medical concepts. This approach fosters practical skills, enhances diagnostic abilities, and promotes a deeper comprehension of the human body's complexities within clinical contexts.
  2. **Practice figures** aid in preparing students for academic examinations by providing hands-on experience with exam-style preparation. It will help to build confidence in tackling the challenges commonly encountered in academic assessments.
  3. **Multiple choice questions (MCQs)** will serve as potent tools for reinforcing learning, assessing comprehension, and enhancing attention and critical thinking skills. Through MCQs, students engage actively with the curriculum, consolidate understanding, and develop the ability to analyse information critically, ultimately fostering deeper comprehension and retention of knowledge.
  4. **Spotters** and **question bank** introduce students to the examination system by familiarising them with the format and types of questions commonly encountered in assessments. These wide ranges of questions will aid the students in preparing for examinations and gaining confidence in tackling examination challenges effectively.

- ***Free access to BDC's Anatomy eBook (digital content through CBSiCentral app):*** It includes the following:
  a. Additional topics and clinical aspects
  b. *Viva voce* questions, and
  c. Topics for further reference and reading.

  This digital resource will enhance the book's utility, providing students with expanded knowledge and resources for comprehensive learning. Accessible supplementary materials will enhance understanding and facilitate deeper exploration, empowering students to excel in their studies and clinical practice.
- **Free Access to CBSiCentral App:** It includes videos of osteology and soft parts and chapter-wise self-assessment MCQ tests. The videos of the dissection will give three-dimensional image descriptions of tissues and organs, which get effectively registered in the brain for a longer time.
- **Wall charts:** Each volume is provided with meticulously crafted wall charts, elegantly designed and tailored to enhance students' comprehension of anatomy. These visually engaging aids can be easily affixed to walls to grasp the visual impressions of anatomy.

Always remember that success is achieved only through diligent effort and hard work.

Chief Editor
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Preface to the First Edition (excerpts)

The necessity of having a simple, systematized and complete book on anatomy has long been felt. The urgency for such a book has become all the more acute due to the shorter time now available for teaching anatomy, and also to the falling standards of English language in the majority of our students in India. The national symposium on 'Anatomy in Medical Education' held at Delhi in 1978 was a call to change the existing system of teaching the unnecessary minute details to the undergraduate students.

This attempt has been made with an object to meet the requirements of a common medical student. The text has been arranged in small classified parts to make it easier for the students to remember and recall it at will. It is adequately illustrated with simple line diagrams which can be reproduced without any difficulty, and which also help in understanding and memorizing the anatomical facts that appear to defy memory of a common student. The monotony of describing the individual muscles separately, one after the other, has been minimised by writing them out in tabular form, which makes the subject interesting for a lasting memory. The relevant radiological and surface anatomy have been treated in separate chapters. A sincere attempt has been made to deal, wherever required, the clinical applications of the subject. The entire approach is such as to attract and inspire the students for a deeper dive in the subject of anatomy.

The book has been intentionally split in three parts for convenience of handling. This also makes a provision for those who cannot afford to have the whole book at a time.

It is quite possible that there are errors of omission and commission in this mostly single-handed attempt. I would be grateful to the readers for their suggestions to improve the book from all angles.

I am very grateful to my teachers and the authors of numerous publications, whose knowledge has been freely utilised in the preparation of this book. I am equally grateful to my professor and colleagues for their encouragement and valuable help. My special thanks are due to my students who made me feel their difficulties, which was a great incentive for writing this book. I have derived maximum inspiration from Prof. Inderbir Singh (Rohtak), and learned the decency of work from Shri SC Gupta (Jiwaji University, Gwalior).

I am deeply indebted to Shri KM Singhal (National Book House, Gwalior) and Mr SK Jain (CBS Publishers & Distributors, Delhi), who have taken unusual pains to get the book printed in its present form. For giving it the desired get-up, Mr VK Jain and Raj Kamal Electric Press are gratefully acknowledged. The cover page was designed by Mr Vasant Paranjpe, the artist and photographer of our college; my sincere thanks are due to him. I acknowledge with affection the domestic assistance of Munne Miyan and the untiring company of my Rani, particularly during the odd hours of this work.

BD Chaurasia

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Videos of bones and soft parts of human body, prepared at Kathmandu University School of Medical Sciences, have now been added with the respective chapters and are available at our mobile App CBSiCentral. We are grateful to Dr R Koju, CEO of Kathmandu University School of Medical Sciences (KUSMS) and Dhulikhel Hospital, for his generosity.

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Editors

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eSmartQuiz – Online MCQ Test

After attending the class, students should go through the "*eSmartQuiz* – Online MCQ test" for the following reasons:

- *Reinforcement of Learning*: The "*eSmartQuiz* – Online MCQ test" provide an opportunity to reinforce learning after attending a class or reading a book. It helps to assess understanding and retention of concepts, to solidify knowledge and identify areas that need further revision or clarification.
- *Assessment of Comprehension*: The "*eSmartQuiz* – Online MCQ test" is an effective tool to assess comprehension of the subject matter and to demonstrate the ability to apply the concepts learned in the class.
- *Enhancement of Attention and Critical Thinking*: The "*eSmartQuiz* – Online MCQ test" will help to make students attentive for the class and to enhance critical thinking skills by selecting the most appropriate answer among the given options.

Each *eSmartQuiz* test consists of 10 MCQs, mostly image-based, and the students can see their scores at the end of each test. These questions will be modified after a certain interval. Use the given links or scan the QR code (given in each chapter) for the test. One student can solve each test only one time.

Chapter	*Link for* ***eSmartQuiz***
Brain–Neuroanatomy	
1. Organisation of Nervous System	https://forms.gle/q3QXQaymKrN8LpvB8
2. Peripheral Nerves and Ganglia	https://forms.gle/ZdAcAbiBLx22dcP19
3. Receptors	https://forms.gle/1By6ddQt6Y1Vf7saA
4. Meninges of the Brain and Cerebrospinal Fluid	https://forms.gle/KsXnZzsHqy6ghy5XA
5. Spinal Cord	https://forms.gle/M5b5xRmq52m64H24A
6. Cranial Nerves and Special Senses	https://forms.gle/H1ws2DKLCctwm8Gx7
7. Brainstem	https://forms.gle/J5E9oiZZ4sZpZzJV6
8. Cerebellum	https://forms.gle/X1b5HvoSK3TqDHSm6
9. Fourth Ventricle	https://forms.gle/FWf7GEgYhPxzUNSS6
10. Diencephalon and Third Ventricle	https://forms.gle/pAsf7NtBmtYSE51r6
11. Cerebrum, Basal Nuclei and White Matter	https://forms.gle/tYvNGezPahWx5dV56
12. Lateral Ventricle and Limbic System	https://forms.gle/JdLkLaob4K1eMdzy8
13. Some Neural Pathways and Reticular Formation	https://forms.gle/E4fzgQp2NKfNkb3W9
14. Blood Supply of Brain	https://forms.gle/8pbcViRGCJ1N67kK6
15. Surface Marking and Radiological Anatomy of Nervous System	https://forms.gle/K5rzTmY6hD8pM6nn9
16. Autonomic Nervous System	https://forms.gle/3q9bCZtNHiA27UDU6
17. Development of Nervous System	https://forms.gle/UMXxbzcC1hA1Rpg88

Index of Competencies

As per the latest NMC Guidelines | Competency Based Medical Education (CBME)
Curriculum under Graduate Medical Education Regulation

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AN57.2	Describe extent of spinal cord in child and adult with its clinical implication	5	30
AN57.3	Draw and label transverse section of spinal cord at midcervical and midthoracic level	5	38
AN57.4	Enumerate ascending and descending tracts at mid thoracic level of spinal cord	5	38
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(*Contd.*)

(Contd.)

Code	*Competency*	*Chapter*	*Page no.*
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Chapter 1

Organisation of Nervous System

Understanding neuroanatomy is crucial for comprehending the nervous system, the primary controlling and coordinating system of the body. It is responsible for judgement, intelligence and memory. It adjusts the body to the surroundings and regulates all bodily activities both voluntary and involuntary. The sensory part of the nervous system collects information from the surroundings and helps in gaining knowledge and experience, whereas the motor part is responsible for responses of the body.

Average weight of adult brain in air is 1500–2000 grams. Since brain floats in cerebrospinal fluid, it only weighs 50 grams which is comfortable. There are about 180–200 billion neurons in an adult brain.

DIVISIONS OF NERVOUS SYSTEM

Anatomical Divisions

It is divided into CNS and PNS (Flowchart 1.1).

Central nervous system (CNS): It which comprises brain and spinal cord. It is responsible for integrating, coordinating the sensory information and ordering appropriate motor actions. CNS is the seat of learning, memory, intelligence and emotions.

Peripheral nervous system (PNS): It includes 12 pairs of cranial nerves and 31 pairs of spinal nerves. These provide afferent impulses to CNS and carries efferent impulses to muscles, glands and blood vessels.

Functional Divisions

Peripheral nervous system functionally has two components:

1. ***Afferent component*** provides sensory information to CNS.
2. ***Efferent component*** carries motor information to muscles, glands, blood vessels and heart via:
    a. ***Somatic nervous system*** for the control of skeletal muscles.
    b. ***Autonomic nervous system*** for control of heart, smooth muscle of the organs, glands and blood vessels. It is subdivided into sympathetic and parasympathetic parts.

CELLULAR ARCHITECTURE

The nervous tissue is made up of:

1. Nerve cells or neurons (Fig. 1.1).
2. Neuroglial cells (neuroglia), forming the supporting (connective) tissue of the CNS. In peripheral nervous system, these are replaced by Schwann's cells.

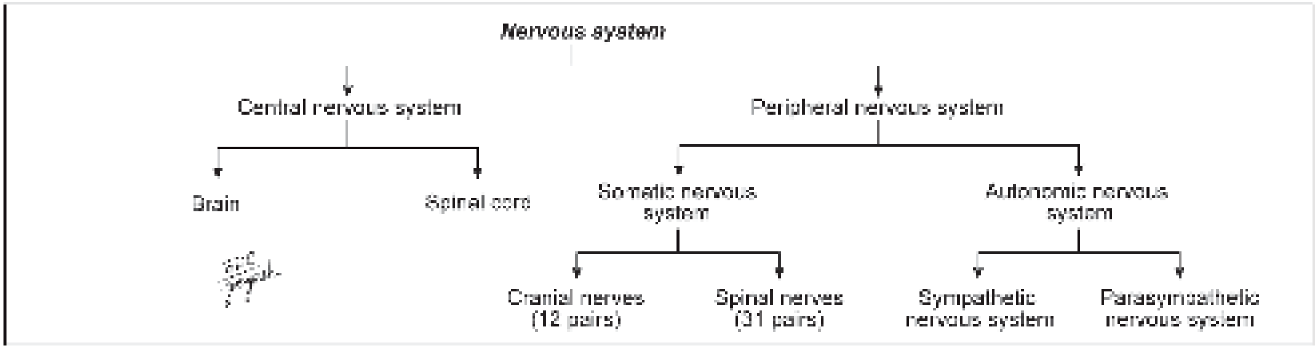
Both types of cells are supplied by abundant blood vessels.

NEURON

Each neuron is made up of the following (Fig. 1.1):

1. ***Cell body*:** Collectively forms grey matter, the nuclei in the CNS, and ganglia in the peripheral nervous system.

Flowchart 1.1: Divisions of nervous system



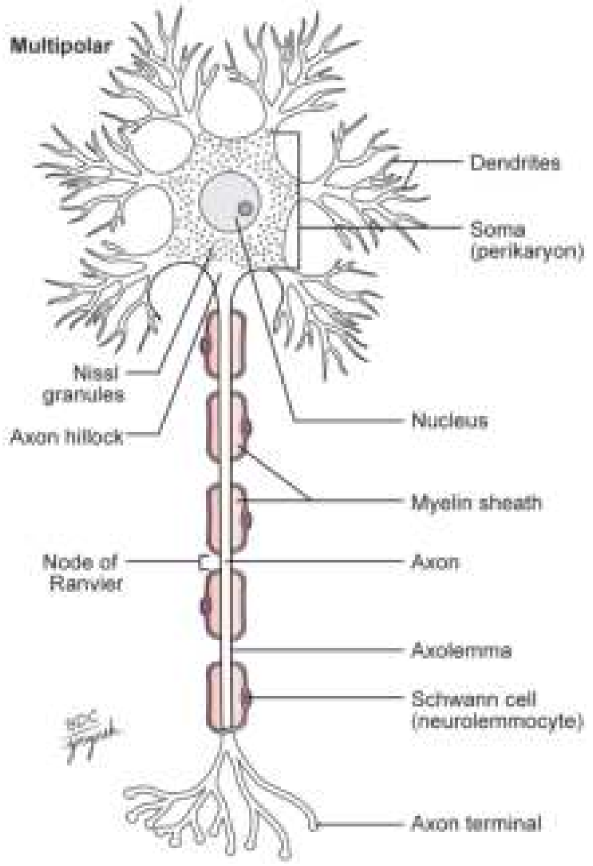

Multipolar
Dendrites
Soma (perikaryon)
Nissl granules
Axon hillock
Nucleus
Myelin sheath
Node of Ranvier
Axon
Axolemma
Schwann cell (neurolemmocyte)
Axon terminal

Fig. 1.1: Multipolar neuron

2. ***Cell processes*** of two varieties:
   a. ***Dendrites*** (Greek *branch of a tree*) are many, short, richly branched and often varicose (Fig. 1.1).
   b. ***Axon*** is a single elongated process. Collectively the axons form tracts (white matter) in the CNS, and nerves in the peripheral nervous system. The branches of axons often arise at right angles and are called the collaterals.

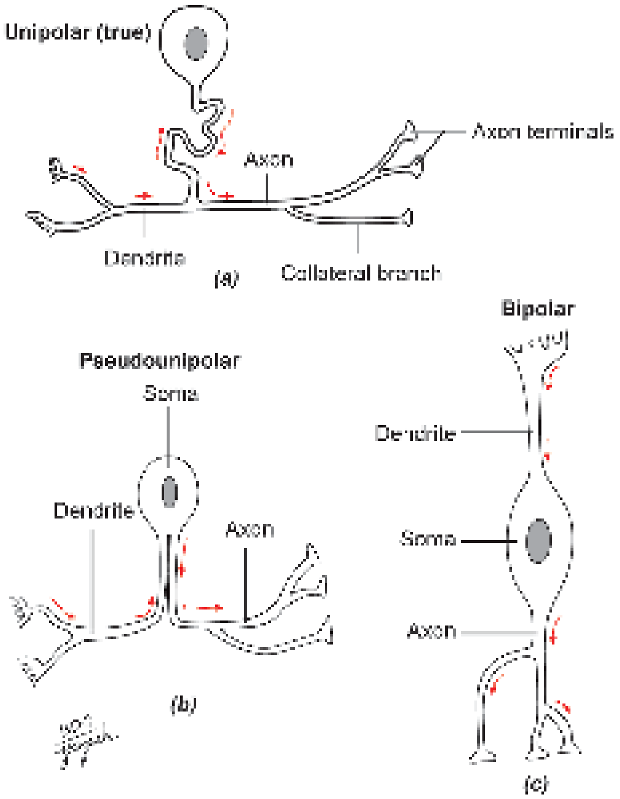
Note: Functionally, each neuron is specialized for sensitivity and conductivity. The impulses can flow in them with great rapidity, in some cases about 125 meters per second. A neuron shows *dynamic polarity* in its processes. The impulse flows towards the cell body in the dendrites, and away from the cell body in the axon.

Classification of Neurons (Flowchart 1.2)

According to the Number of their Processes

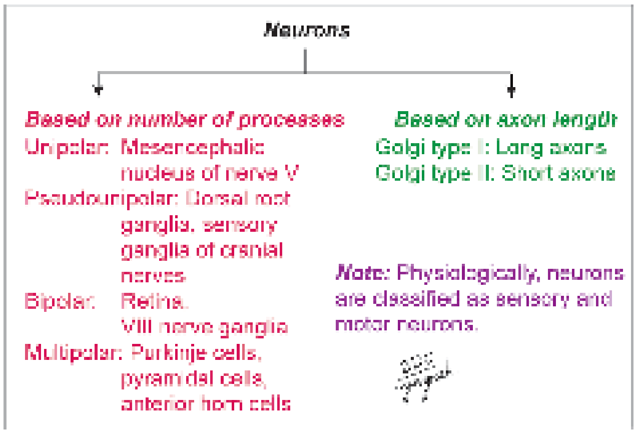
1. ***Unipolar neurons:*** They are present in the mesencephalic nucleus of trigeminal nerve and also occur during foetal life. These cells are more common in lower vertebrates (Fig. 1.2a).
2. ***Pseudounipolar neurons:*** They are actually unipolar to begin with but become bipolar functionally and are found in dorsal nerve root ganglia and sensory ganglia of the cranial nerves (Fig. 1.2b).

   Note: New concept: Unipolar and pseudounipolar neurons are under the same category [Pawlina, Histology, 7th edition].
3. ***Bipolar neurons:*** They are confined to the first neuron of the retina, ganglia of 8th cranial nerve, and the olfactory mucosa (Fig. 1.2c).


Unipolar (true)
Axon terminals
Axon
Dendrite
(a)
Collateral branch
Pseudounipolar
Soma
Dendrite
Axon
(b)
Bipolar
Dendrite
Soma
Axon
(c)

Figs 1.2a to c: Types of neurons (schematic)

Flowchart 1.2: Classification of neurons


Neurons
Based on number of processes
Unipolar: Mesencephalic nucleus of nerve V
Pseudounipolar: Dorsal root ganglia, sensory ganglia of cranial nerves
Bipolar: Retina, VIII nerve ganglia
Multipolar: Purkinje cells, pyramidal cells, anterior horn cells
Based on axon length
Golgi type I: Long axons
Golgi type II: Short axons
Note: Physiologically, neurons are classified as sensory and motor neurons.

4. ***Multipolar neurons:*** Most of the neurons in human are multipolar, e.g. all motor and internuncial neurons (Fig. 1.1).

According to Length of Axon

Golgi type I: These neurons have long axons and numerous short dendrites. These are seen in pyramidal cells of cerebral cortex, Purkinje cells of cerebellum (Fig. 1.3) and anterior horn cells of spinal cord.

Golgi type II: These are neurons with short axons, and establish synapses with neighbouring neurons. These are also seen in cerebral and cerebellar cortices.

Note: ***Amacrine neurons*** are without axon, only with dendrite. They are seen in retina of eyeball.

Mature neuron is incapable of dividing. Recently some neurons in olfactory region and hippocampus have been seen to divide. Brain tumours arise chiefly from the neuroglial cells.

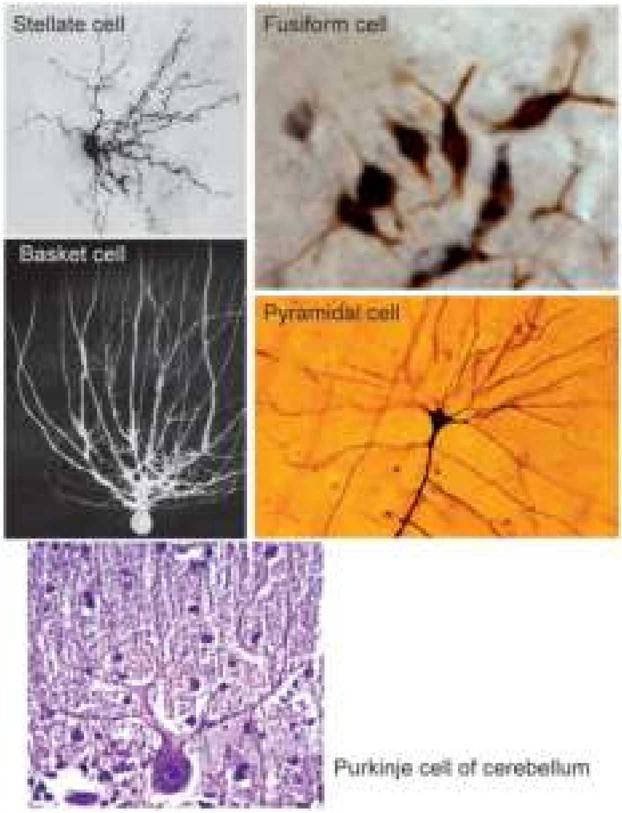


Fig. 1.3: Types of neurons (photomicrograph)

Functional Classification

Neurons are classified into sensory neurons, motor neurons and autonomic neurons, i.e. parasympathetic and sympathetic neurons.

Sensory neurons: They receive impulses and carry signals to the nervous system. These are of three types:

1. *Primary or 1st order sensory neurons* are present as spinal or sensory neurons in the dorsal root ganglion of spinal nerves.
2. *Secondary or 2nd order sensory neurons* are present in the grey matter of spinal cord and in brainstem.
3. *Tertiary or 3rd order sensory neurons* are seen in thalamus.

Motor neurons: These carry impulses from CNS to distal part of the body. These somatic motor neurons are of two types:

1. *Upper motor neurons* are situated in motor area of brain. These synapse with cranial nerve nuclei and anterior horn of spinal cord.
2. *Lower motor neurons* are located in cranial nerve nuclei and anterior horn of spinal cord. Nerves emerging from these nuclei supply the various skeletal muscles.

Parasympathetic neurons (autonomic)

1. Preganglionic neurons are located in cranial nerves III, VII, IX and X, also in sacral 2–4 segments of the spinal cord.
2. Postganglionic neurons are located close to the wall or within the wall of the viscera.
3. Parasympathetic outflow is called 'craniosacral outflow'.

Sympathetic neurons (autonomic)

1. Preganglionic neurons are located in the lateral horn of thoracic, and first and second lumbar segments of the spinal cord.
2. Postganglionic neurons are situated in the ganglia of the sympathetic trunk away from the viscera.
3. Sympathetic outflow is called 'thoracolumbar outflow'.

Note: The neurons can be classified according to shape as stellate, basket, fusiform, and pyramidal.

These can be also classified according to size as *macroneuron* (>7 μm size), e.g. Betz cells and *microneuron* (< 7 μm size), e.g. granular cells.

Structure of Neuron

A neuron has a body, axon, dendrites, and synaptic junctions (Fig. 1.1).

Body/Perikaryon

1. The cell body of a neuron is also called perikaryon or soma. It consists of the nucleus, perinuclear cytoplasm, and cell membrane.
2. ***Cytoplasm*** contains a large central vesicular nucleus, numerous mitochondria, rough endoplasmic reticulum, and Golgi complex. The nucleus is euchromatic (lightly stained) with 1–2 nucleoli.

   Note: New concept: Neurons have centrioles, but they cannot divide (*Previous concept*: Neurons do not have centrioles).
3. *Nissl bodies/substance/granules:* The cytoplasm of neurons shows the presence of granular *basophilic* cytoplasmic material (blue coloured on *H&E staining*) called Nissl bodies. On electron microscopy, Nissl bodies are stacks of the rough endoplasmic reticulum.
4. The neuron contains many *neurofibrils* (microtubules and microfilaments). Centrioles may help in the production of neurofibrils. Some of the neurons also contain melanin pigment (substantia nigra) and lipofuscin pigments.

Neurites

The processes arising from the cell body of a neuron are called *neurites*. They are axons and dendrites.

Dendrites

These are multiple, short, thick, tapering processes. Nissl granules extend into the dendrites. The branching pattern of dendrites (*arborization*) is called *dendritic tree*. Dendrites receive information and carry it toward the body of the cell.

Axons

1. Axon is a single, long, and thin process of neuron. Axons carry information away from the neuron body and have a uniform diameter. Axon is devoid of Nissl granules.
2. *Axoplasm* is cytoplasm in axon and *axolemma* is its cell membrane.
3. *Axoplasmic transport* (axonal transport system): As axons do not contain rough endoplasmic reticulum,

the protein synthesized in the cell body needs to be transported across axon.

Note: New concept: Periaxoplasmic plaques – these are axon terminals that have protein synthesis machinery (rER). These are involved in the process of neuronal cell memory.

4. *Axon hillock*: It is a part of cell body that is devoid of Nissl granules and gives rise to axon.

Note: New concept: Some cells of the olfactory bulb and dentate gyrus of the hippocampus are neural stem cells and they can generate new neurons [*Pawlina*, *Histology*, *7th edition*].

5. *Initial segment*: It is the initial *nonmyelinated* part of axon between axon hillock and myelinated part of axon. An action potential is generated at initial segment.

The differences between axons and dendrites are listed in Table 1.1.

SYNAPSE

The neurons are connected to one another by their processes, forming long chains along which the impulses are conducted. The site of contact (contiguity without continuity) between the nerve cells is known as *synapse* (Greek *together*) (Fig. 1.4).

One cell may establish such contacts through its dendrites with as many as 1000 axonal terminals. However, it must be remembered that each neuron is an independent unit and the contact between neurons is by contiguity and not by continuity ('neuron theory' of Waldeyer, 1891). The impulse is transmitted across a synapse through biochemical neurotransmitters (acetylcholine).

Morphological Classification

Depending on components of the synapse, they are classified as follows (Fig. 1.4):

1. *Axodendritic synapse*: It is the most common type of synapse. In the axodendritic synapse, the axon of one neuron synapses with the dendrite of another neuron.
2. *Axosomatic synapse*: Axon conveys impulses to soma (body) of another neuron.
3. *Axoaxonic synapse*: It is the synapse between two axons.
4. *Dendroaxonic synapse*: It is the synapse between dendrite of presynaptic neuron and axon of postsynaptic neuron. It is seen in some parts of thalamus.

TABLE 1.1: Differences between axon and dendrites

Axon	*Dendrites*
It is a single, long, thin process of neuron	These are multiple, short, thick processes of neuron
It carries signal away from nerve cell body	It carries signal toward nerve cell body
Axon rarely branches Branches of axon form axon terminals	Branches of dendrite form dendritic tree
Diameter: Uniform	Diameter: Taper toward distal end (away from neuron)
Does not contain Nissl granules	Contain Nissl granules

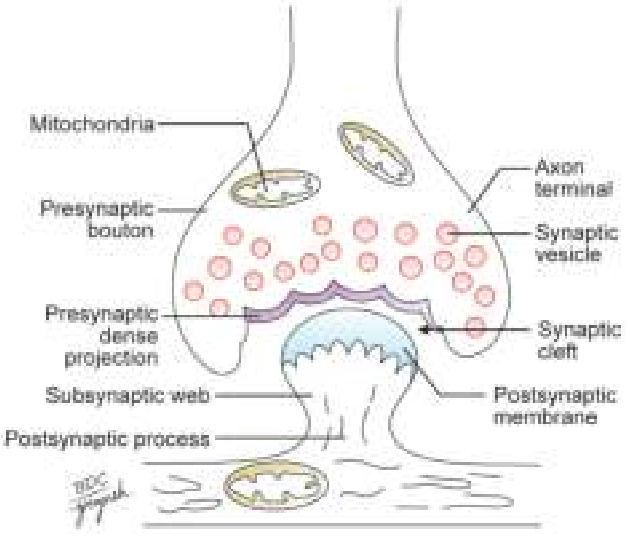


Fig. 1.4: Structure of a synapse neurotransmitters (acetylcholine)

5. *Dendrodendritic synapse*: It is the synapse between two dendrites.
6. *Somatosomatic synapse*: It is the synapse between bodies of neurons.
7. *Somatodendritic synapse*: It is the synapse between soma and dendrite of postsynaptic neurons.

Note: Synapse is not distinguishable on *H&E staining*.

Boutons en passant: Presynaptic neuron makes several contacts with postsynaptic neuron. These contacts are called boutons en passant (means *buttons in passing* in French).

Silver staining (Golgi method): Synapse is visible as oval bodies.

Bouton terminal: Enlarged terminal end of axon is called bouton terminal (means *terminal button* in French).

Chemical and Electric Synapses

Based on mechanism of conduction of nerve impulses, synapses are classified as chemical or electrical.

Chemical synapses

The chemical synapse involves release of chemical (neurotransmitter) from preganglionic neurons for conduction of impulse.

Structure of chemical synapse (Fig. 1.4): The components of chemical synapse are as follows:

1. *Presynaptic element* (*presynaptic knob*) is the part of presynaptic neuron that releases neurotransmitter. Presynaptic element stores neurotransmitter in synaptic vesicles.
2. *Synaptic cleft* is a narrow gap (20–30 nm) between presynaptic and postsynaptic neurons. Neurotransmitter needs to cross synaptic cleft.
3. *Postsynaptic membrane/process* is a membrane of postsynaptic neuron that has receptors for neurotransmitters.

Note: *New concept*: *Porocytosis* is a process of secretion of neurotransmitters through pores created by calcium ions between secretory vesicles and presynaptic membrane (*Previous concept*: Secretory vesicle fuses with presynaptic membrane for the release of neurotransmitter).

Electrical synapses

The electric synapse involves the passage of electric signal from one cell to another cell by gap junctions. Electrical synapses do not involve neurotransmitter release.

Examples: Gap junctions of cardiac and smooth muscles.

NEUROGLIAL CELLS

The supporting cells of the nervous system are called *neuroglia* or *glia*. They are grouped as follows (Flowchart 1.3, Plate 1.1, and Table 1.2):

1. Central neuroglia (neuroglia of the central nervous system).
2. Peripheral neuroglia (neuroglia of the peripheral nervous system).

Central Neuroglia

These are supporting cells of the central nervous system. There are four types of central neuroglia:

Astrocytes, oligodendrocytes, microglia, and ependymal cells. These cells support embryonic (developing) neurons as well as provide physical support after development.

Astrocytes

These are star-shaped cells (largest neuroglia) and they have numerous processes. There are two types of astrocytes: Fibrous and protoplasmic.

1. *Fibrous astrocytes* have fewer and thin processes and are mostly found in the white matter of the CNS.
2. *Protoplasmic astrocytes* have numerous, short, thick, branching cytoplasmic processes. They are mostly found in grey matter.

Functions of astrocytes

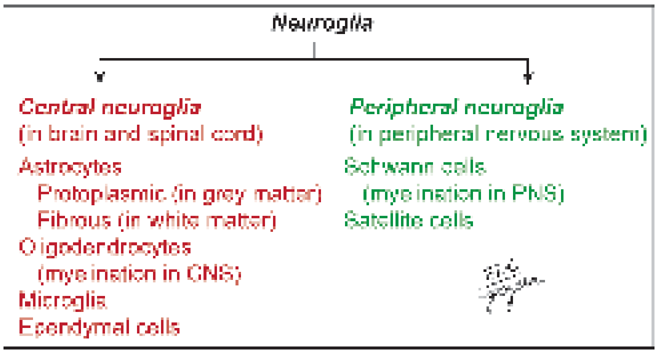
- They provide physical support to neurons.
- They maintain a favourable metabolic environment for neurons by removing neurotransmitters from synapses. They store glycogen.
- They help in the maintenance of the blood-brain barrier.
- Astrocytes maintain K^+ ion concentration in extracellular spaces of the brain and spinal cord by potassium spatial buffering.

Note: Glia limitans is the membrane-like barrier on external surfaces of brain and spinal cord. It is produced by protoplasmic astrocytes. *Gliosis* is the proliferation of astrocytes to heal the damaged zones of nervous tissue. *Fibrous astrocytoma* (tumour) accounts for about 80% of brain tumours in adults.

Oligodendrocytes

The oligodendrocytes are small, round cells and have a few cytoplasmic processes (*oligo* = scanty, in Greek). They produce myelin in CNS. One oligodendrocyte myelinates many adjacent axons or sometimes the same axons at different places. The gap between adjacent processes of oligodendrocytes that myelinate an axon is called node of Ranvier. The myelin sheath in CNS differs from that of PNS in protein expression.

Flowchart 1.3: Types of neuroglia



Function: Oligodendrocytes produce myelin sheaths in CNS.

Note: The myelin in CNS has fewer *Schmidt–Lanterman clefts* because astrocytes provide favourable metabolic environment to neurons. Oligodendrocytes do not have external lamina (as it is present in Schwann cells). Nonmyelinated neurons are not enclosed by processes of oligodendrocytes in CNS.

Microglia

These are the smallest neuroglial cells. These are involved in phagocytosis when they become active (reactive microglial cells). These are derived from mesoderm (bone marrow). They are small cells with few cytoplasmic processes and elongated nuclei.

Function: Microglia are phagocytic cells. They proliferate specifically in nervous tissue injuries and diseases. Microglia form a part of mononuclear phagocytic system in CNS.

Note: *Current update*: Microglia remove bacteria, cancer (neoplastic) cells, and dead nerve cells. *Gitter* or *Hortega cell* is a lipid-laden microglial cell observed at the edge of healing brain infarcts. It is also called compound granule cell, gitterzelle, mesoglea, or perivascular glial cell.

Ependymal Cells

The cavities of the nervous system are lined by epithelium-like *ependymal cells*. Ependymal cells are cuboidal to columnar in shape and arranged in a single layer. These cells are derived from neural tube.

There are three types of ependymal cells: Ependymocytes, choroid epithelial cells, and tanycytes.

Functions

1. Exchange of substances between the brain and cerebrospinal fluid at the brain–CSF barrier.
2. Choroid plexus secretes CSF.
3. Tanycytes: Respond to glucose concentration changes.

Note: Most of the brain cavities are lined by ependymocytes except at:

1. Choroid plexuses are lined by *choroid epithelial cells* that secrete cerebrospinal fluid.
2. Floor of third (not fourth) ventricle is lined by *tanycytes* (specialized ependymal cells). These cells are *sensitive to changes in glucose concentration* and monitor levels of metabolites.

Plate 1.1: Types of neuroglial cells

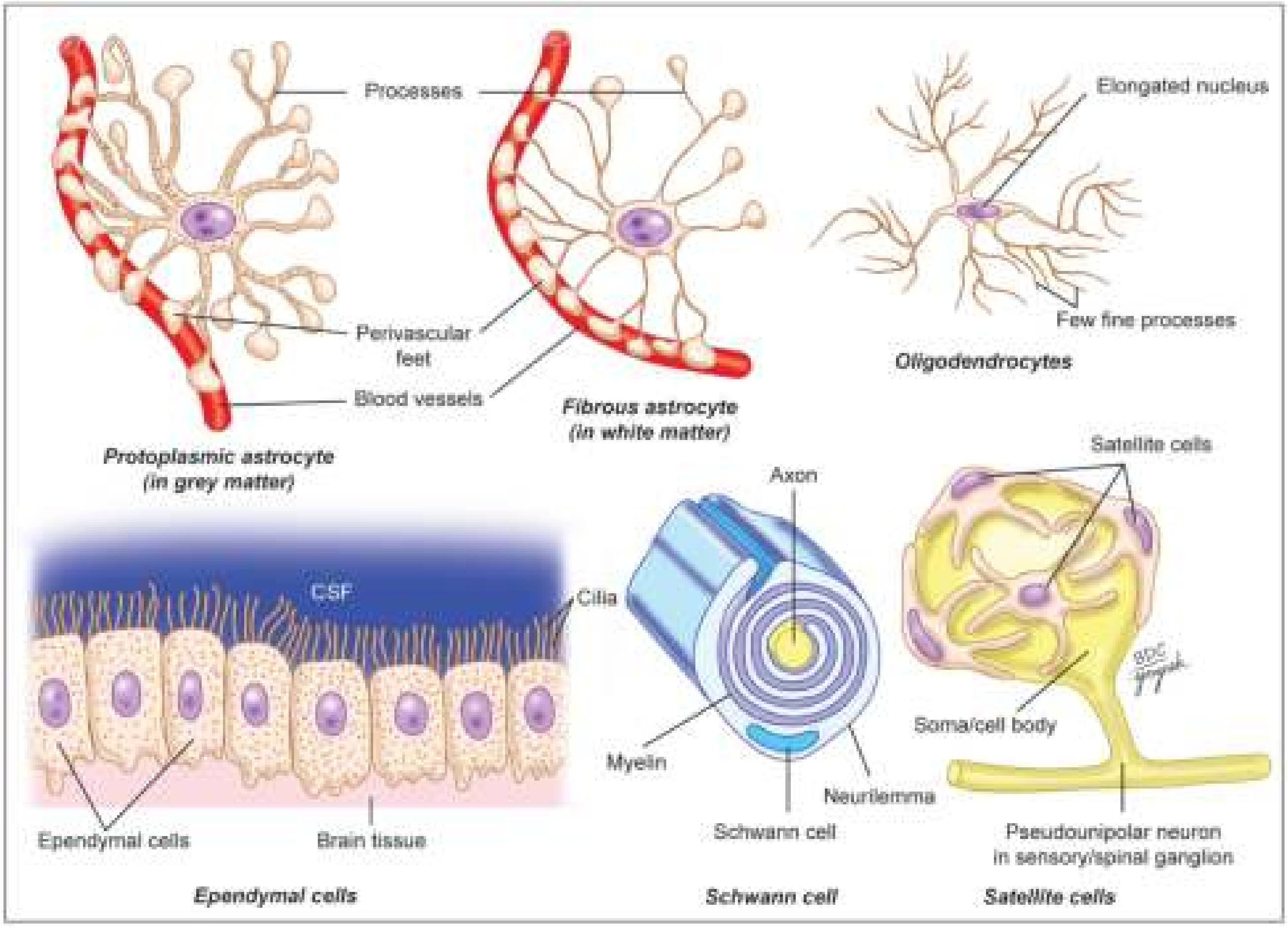

Processes
Perivascular feet
Blood vessels
Protoplasmic astrocyte (in grey matter)
Fibrous astrocyte (in white matter)
Elongated nucleus
Few fine processes
Oligodendrocytes
CSF
Cilia
Ependymal cells
Brain tissue
Ependymal cells
Axon
Myelin
Neurilemma
Schwann cell
Schwann cell
Satellite cells
Soma/cell body
Pseudounipolar neuron in sensory/spinal ganglion
Satellite cells

TABLE 1.2: Types of neuroglial cells

	Protoplasmic astrocyte	*Fibrous astrocyte*	*Oligodendrocyte*	*Microglia*
Cell size	Large	Large	Medium	Small, elongated
Shape of nucleus	Oval, light stained	Oval, light stained	Small, spherical, dark stained	Small, elongated, dark stained
Cytoplasmic processes	Many, short and thick	Many long slender	Few, short, beaded	Short, thin, spinous
Cytoplasm	Granular	Fibrillar	—	—
Situation	Grey matter	White matter	White matter	Grey and white matters
Function	Blood–brain barrier (BBB)	BBB	Myelination	Phagocytosis
Embryological origin	Neural crest	Neural crest	Neural crest	Mesoderm

Peripheral Neuroglia

Schwann Cells

These are also called *neurolemmocytes*. These are present only in peripheral nervous system. These cells are flattened cells with a flattened nucleus that is surrounded by abundant cytoplasm. They are derived from neural crest cells.

Functions: Schwann cells produce myelin in peripheral nervous system.

Satellite Cells

In the ganglia (collection of neuronal cell bodies outside the CNS), neuronal bodies are surrounded by a layer of flat cuboidal cells called satellite cells. These cells work similar to Schwann cells but do not produce myelin.

Satellite cell capsule gives passage to nerve cell processes. In sensory ganglia, the satellite cell capsule is nearly complete as sensory neurons do not synapse in ganglia. In autonomic ganglia, the satellite cell capsule is not complete as autonomic neurons have synapses in the ganglia.

Functions: Protection and support ganglionic neurons.

CLINICAL NEUROANATOMY

- ***Gliosis***: Proliferation of glial cells is called the ‘gliosis’. A CNS lesion heals by gliosis. A spontaneous gliosis is an indication of a degenerative change in the nervous tissue.
- ***Brain tumours***: Since the glial cells are capable of dividing, they can form CNS tumours.

GREY MATTER AND WHITE MATTER

Unit of nervous tissue is the neuron, comprising of cell body, dendrites and axon. Neurons are supported by neuroglia and blood vessels.

Grey matter is the part of nervous tissue containing the cell body (soma), neuroglial cells and abundance of blood vessels. It covers the outer aspect of brain and is known as the cortex. Grey matter present within the depth of white matter is called ganglia/nuclei.

White matter comprises only the fibres, i.e. axons, dendrites, neuroglial cells and fewer blood vessels. In the brain, the white matter lies deep to the cortex of brain. In the spinal cord, the white matter lies superficial to the deeply placed 'H-shaped' grey matter.

REFLEX ARC

A reflex arc is the functional unit of the nervous system. In its simplest form (monosynaptic reflex arc), it consists of:

1. Receptor, e.g. the skin/muscle
2. Sensory neuron
3. Motor neuron
4. Effector, e.g. the muscle.

An involuntary motor response to a sensory stimulus is known as the *reflex action*. These are of two types:

1. Cortical responses which are voluntary in nature.
2. Subcortical responses which are involuntary.

Reflex action is chief function of spinal cord. Knee jerk and ankle jerk are monosynaptic reflex arcs (Figs 1.5 and 1.6). Some common reflex arcs are shown in Table 1.3.

PARTS OF THE NERVOUS SYSTEM

CENTRAL NERVOUS SYSTEM (CNS)

Components of Central Nervous System

Spinal cord: It receives sensory information from the skin, joints, and muscles of the trunk and limbs and contains

TABLE 1.3: Some common reflexes

Name of reflex	*Way of eliciting*	*Result*	*Comment*
Biceps jerk	Striking biceps brachii tendon	Flexion of the elbow joint	C5, C6 segments intact Tendon jerks may be exaggerated in upper motor neuron lesion or lost in lower motor neuron lesion
Triceps jerk	Striking triceps brachii tendon	Extension of the elbow joint	C7, C8 segments intact
Knee jerk (Fig. 1.5)	Striking the ligamentum patellae	Extension of the knee joint	L3, L4 segments of spinal cord intact
Ankle jerk	Striking tendo calcaneus	Plantar flexion of the ankle joint	S1, S2 segments intact
Abdominal reflex	Striking a quadrant of abdomen	Contraction of abdominal muscles	Positive reflex indicates normal pyramidal tract with T7–T12 nerves intact
Plantar reflex	Scratching the sole of foot from lateral side towards big toe	Plantar flexion of the great toe and other toes	A normal plantar response indicates intact pyramidal tract
Babinski's sign (Fig. 1.6)	Same as in plantar reflex	Dorsiflexion of the great toe and fanning of other toes	Babinski's sign indicates pyramidal tract injury, except in infants

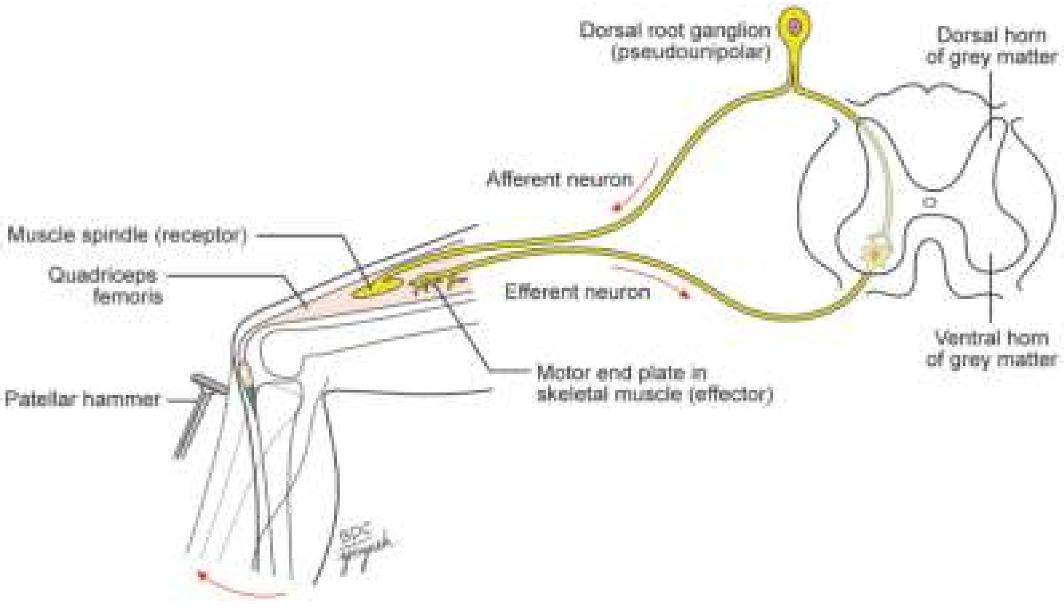

Dorsal root ganglion (pseudounipolar)
Dorsal horn of grey matter
Afferent neuron
Muscle spindle (receptor)
Quadriceps femoris
Efferent neuron
Patellar hammer
Motor end plate in skeletal muscle (effector)
Ventral horn of grey matter

Fig. 1.5: Components of the knee jerk

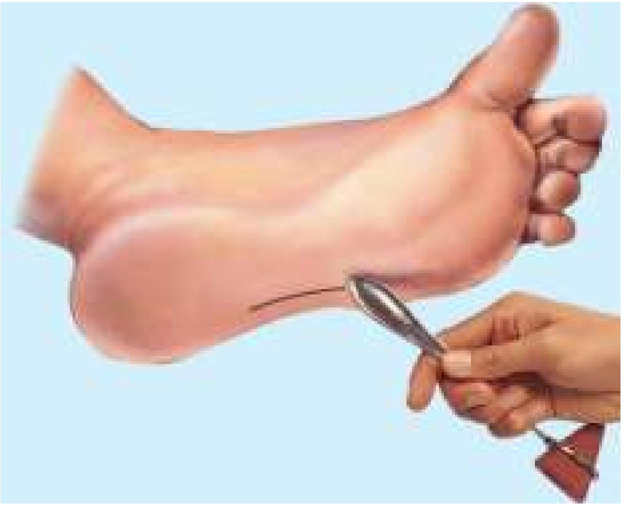


Fig. 1.6: Babinski's sign

the motor neurons responsible for both voluntary and reflex movements. It has central grey matter and peripheral white matter.

***Brainstem*:** It includes:

a. *Medulla*: This is the direct rostral extension of the spinal cord.
b. *Pons*: It lies rostral to the medulla.
c. *Midbrain*: This is the smallest brainstem component which lies rostral to the pons.

***Cerebellum*:** The cerebellum lies dorsal to the pons and medulla. The cerebellum plays a major role in the control of tone, equilibrium and posture, including head and eye movements.

***Diencephalon*:** It includes the thalamus, hypothalamus epithalamus and metathalamus. It is present between the cerebral hemispheres and the midbrain. The hypothalamus lies ventral to the thalamus.

Cerebral hemispheres: This is the largest region of the brain. It consists of the cerebral cortex/grey matter and the fibres which form white matter with deeply located nuclei: The basal ganglia, the hippocampal formation and the amygdala. Each hemisphere comprises 4 lobes, e.g. frontal, parietal, temporal and occipital lobes. Each hemisphere has a flat medial surface which lie adjacent to each other separated by a longitudinal fissure. In the lower part of the fissure is present a thick band of fibres—the corpus callosum. The hemisphere shows infoldings in the form of sulci and gyri, giving more space for the neurons.

***Ventricles of brain*:** Ventricles are continuous cavities in various parts of brain as follows:

1. *Lateral ventricle* is cavity of each cerebral hemisphere.
2. *Third ventricle* is present between the two thalami. It continues as *aqueduct* of midbrain.
3. *Fourth ventricle* is cavity of hindbrain, i.e. pons, medulla and cerebellum and continues downwards as *central canal of spinal cord*.

CSF circulation in the ventricles and subarachnoid space provides nourishment to the components of brain.

***Protective coverings*:** Brain and spinal cord are covered by 3 meninges with intervening spaces. The outermost is the dura mater, middle layer is delicate cobweb-like arachnoid mater and the inner one is the pia mater. The subdural space is very narrow while the subarachnoid space is big containing very important cerebrospinal fluid.

PERIPHERAL NERVOUS SYSTEM

Somatic (cerebrospinal) nervous system: It is made up of 12 pairs of cranial nerves and 31 pairs of spinal nerves. Its efferent fibres reach the effectors without interruption (Fig. 1.7a).

Autonomic (splanchnic) nervous system: It consists of sympathetic and parasympathetic systems. Its efferent fibres first relay in a ganglion, and then the postganglionic fibres pass to the effectors (Figs 1.7b and c).

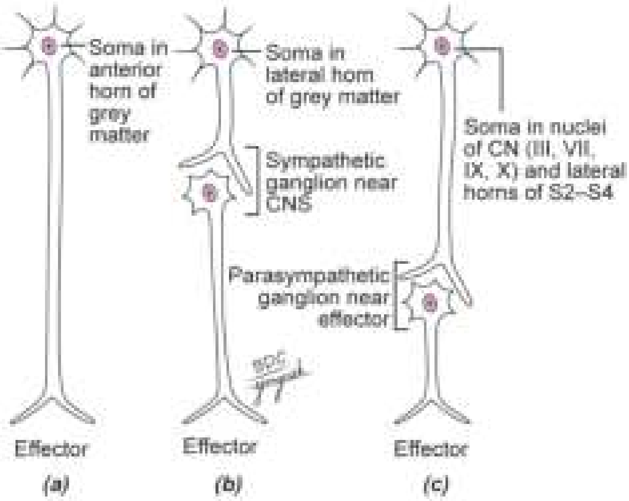
GROSS STUDY OF BRAIN

Learning neuroanatomy is beginning of a journey in gaining knowledge of our own brain. The knowledge of the nervous system will be helpful in the field of medicine for understanding neurophysiology, neuropathology, neuropharmacology, and many diseases that will encounter during clinical practice.

The brain can be studied by viewing it from different views such as superior, inferior, anterior, posterior, lateral, and medial (Plate 1.2).

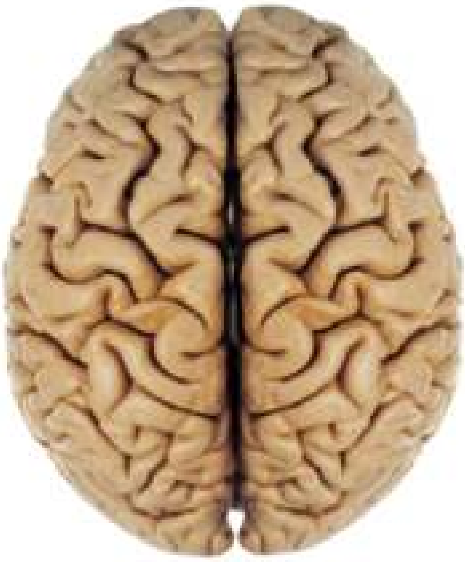
For the study purposes, the brain can be cut in the following planes (Plate 1.3):

1. *Coronal plane* – When brain is cut through dorsal and ventral surfaces in the coronal plane.
2. *Horizontal plane* – When it is cut from side-to-side.
3. *Sagittal plane* – When brain is cut in relation to longitudinal axis, i.e. from anterior to posterior aspect.
4. *Oblique plane* – When brain is cut at an angle from cerebral cortex down through the brainstem.

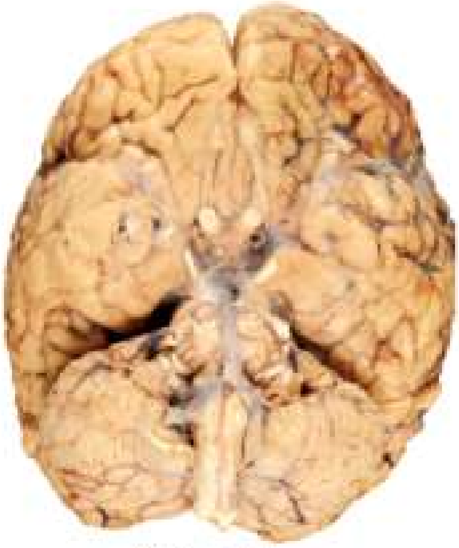

Soma in anterior horn of grey matter
Soma in lateral horn of grey matter
Sympathetic ganglion near CNS
Soma in nuclei of CN (III, VII, IX, X) and lateral horns of S2–S4
Parasympathetic ganglion near effector
Effector
(a)
Effector
(b)
Effector
(c)

Figs 1.7a to c: Types of peripheral nervous system: (a) Somatic, (b) sympathetic and (c) parasympathetic

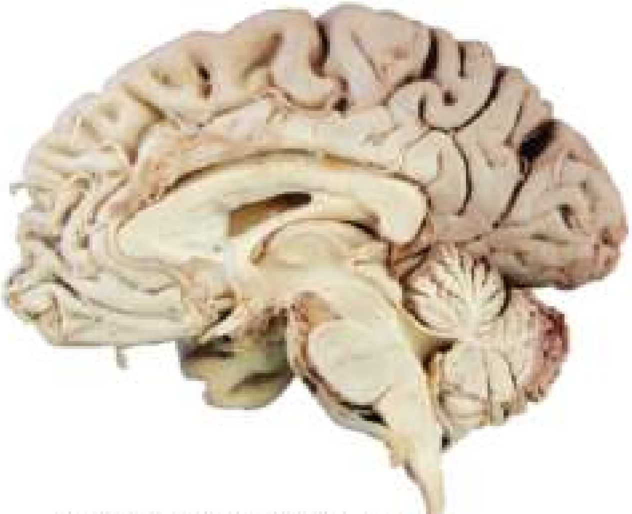
Plate 1.2: Various views of the brain



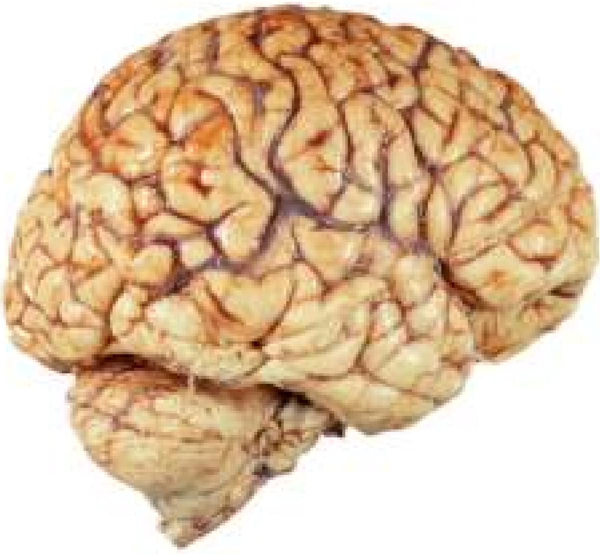
(a) Superior view



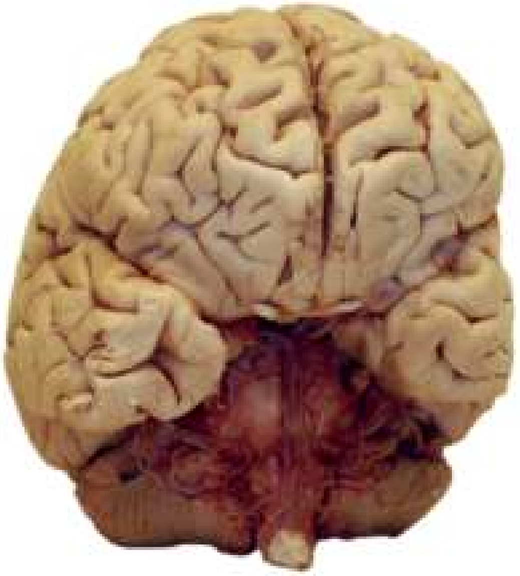
(b) Ventral view



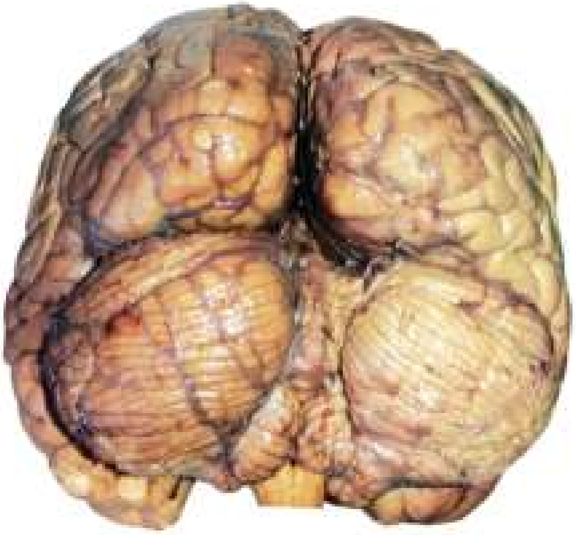
(c) Medial view (right hemisphere)



(d) Right superolateral surface

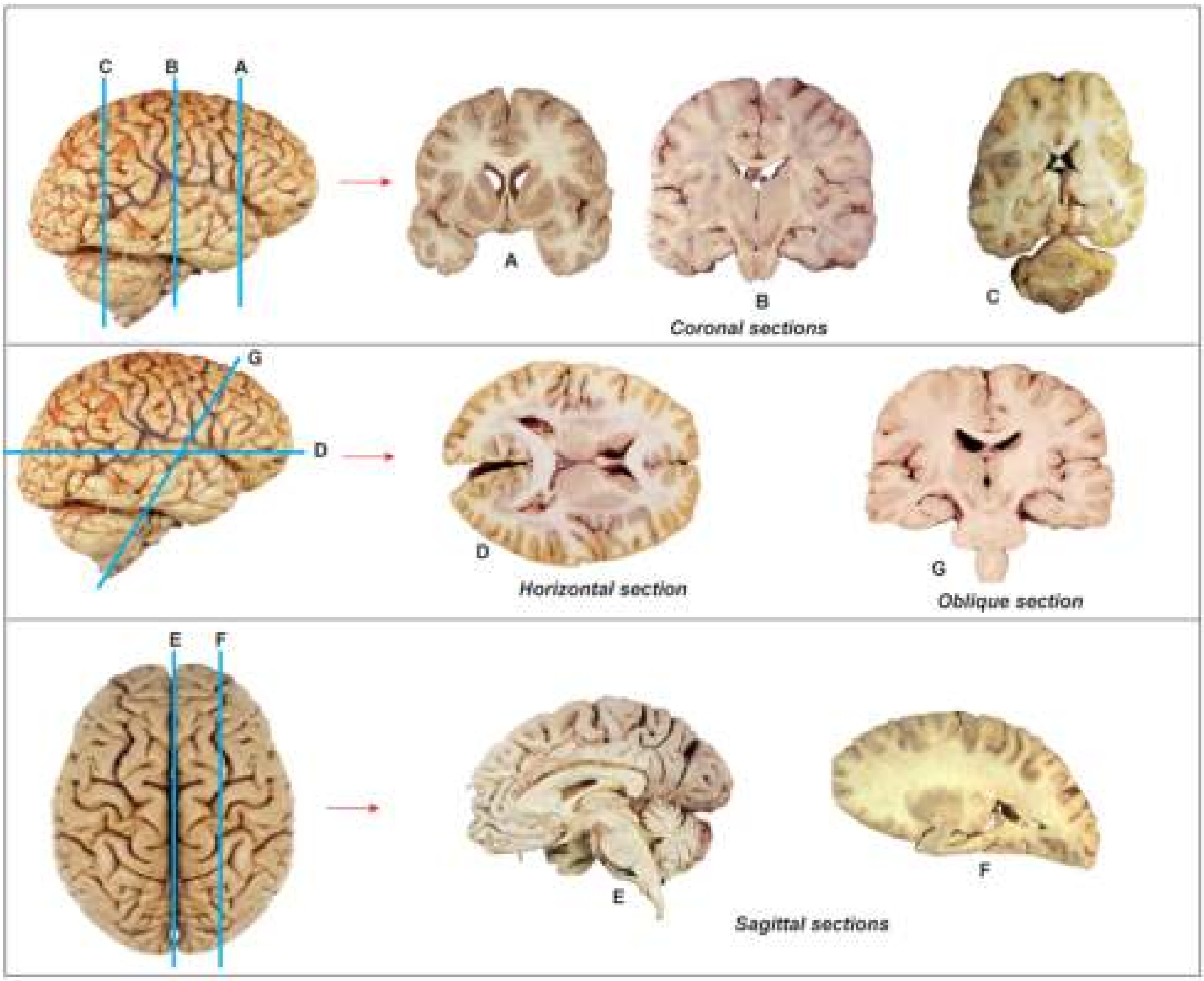


(e) Anterior view



(f) Posterior view

Plate 1.3: Sections of brain in different planes: A to C—coronal sections; D—horizontal section; E and F—sagittal sections; G—oblique section



PARTS OF BRAIN

The brain has forebrain, midbrain and hindbrain. The main parts and their subdivisions of the forebrain are shown in Table 1.4, and Figs 1.8 and 1.9. The brainstem includes the midbrain, pons and medulla. Hindbrain includes pons, medulla and cerebellum.

The dilated part of the central canal of spinal cord within the conus medullaris is known as the terminal ventricle. Similarly, the cavity of septum pellucidum is sometimes called the fifth ventricle.

TABLE 1.4: Parts of brain and their subdivisions

Parts	*Subdivisions*	*Cavity*
1. Forebrain (prosencephalon)	A. Telencephalon (cerebrum), made up of two cerebral hemispheres and the median part in front of the interventricular foramen	Lateral ventricle
	B. Diencephalon (thalamencephalon), hidden by the cerebrum, consists of: a. Thalamus b. Hypothalamus c. Metathalamus, including the medial and lateral geniculate bodies, and d. Epithalamus, including the pineal body, habenular trigone and posterior commissure e. Subthalamus	Third ventricle
2. Midbrain (mesencephalon)	Crus cerebri, substantia nigra, tegmentum, and tectum, from before backwards	Cerebral aqueduct
3. Hindbrain (rhombencephalon)	A. Metencephalon, made up of pons and cerebellum B. Myelencephalon or medulla oblongata	Fourth ventricle

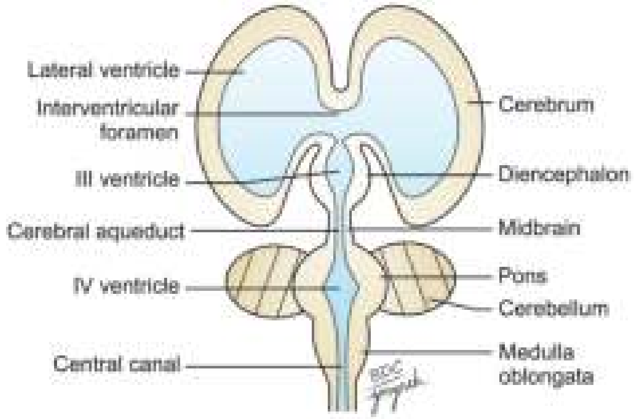

Lateral ventricle
Interventricular foramen
III ventricle
Cerebral aqueduct
IV ventricle
Central canal
Cerebrum
Diencephalon
Midbrain
Pons
Cerebellum
Medulla oblongata

Fig. 1.8: Parts of the brain

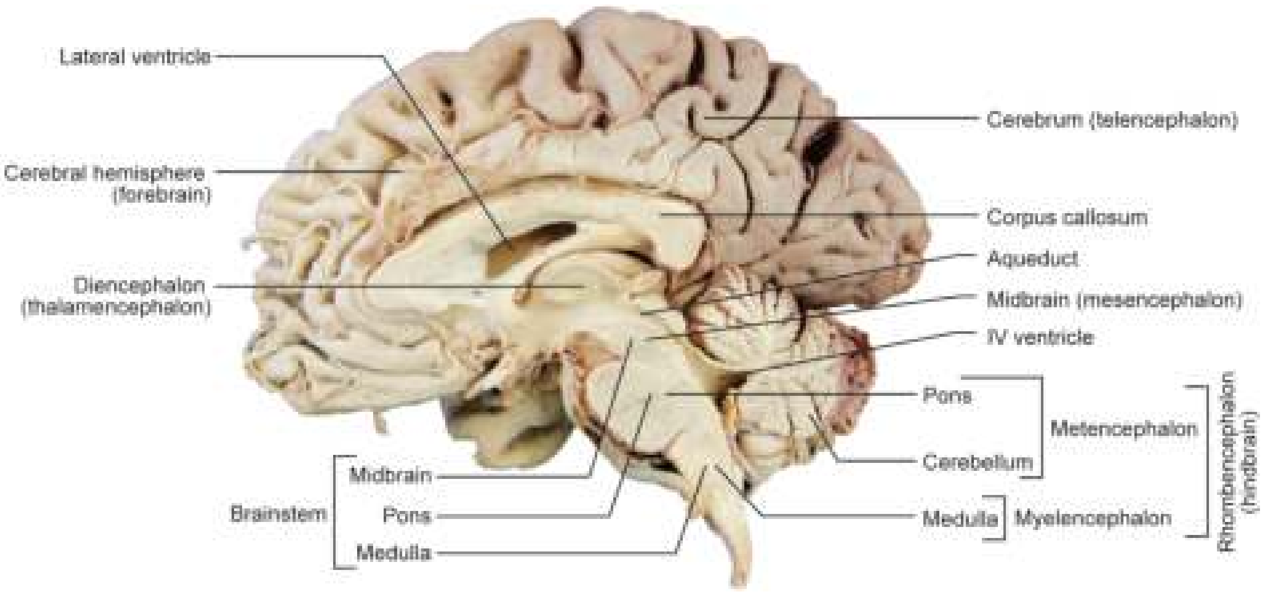

Lateral ventricle
Cerebral hemisphere (forebrain)
Diencephalon (thalamencephalon)
Brainstem
Midbrain
Pons
Medulla
Cerebrum (telencephalon)
Corpus callosum
Aqueduct
Midbrain (mesencephalon)
IV ventricle
Pons
Cerebellum
Metencephalon
Medulla
Myelencephalon
Rhombencephalon (hindbrain)

Fig. 1.9: Parts of the brain (dissection)

Facts to Remember

- Neurons in human brain are about 180–200 billion.
- Unipolar neurons are present only in the mesencephalic nucleus of 5th cranial nerve.
- Nissl granules are the rough endoplasmic reticulum. They are absent in the axon hillock and axon.
- Mature neurons do not divide after birth except in olfactory region and in hippocampus.
- Impulse travels from dendrite to cell body and then into axon.
- Contact between neurons is by contiguity (like hand shake) and not by continuity.
- Ependymal cells are responsible for the formation of cerebrospinal fluid. Astrocytes form the blood–brain barrier.

BDC's Anatomy e-book

1. Further reading
2. Viva voce questions

Chapter 2

Peripheral Nerves and Ganglia

The peripheral nerves form a communication between the organs and the central nervous system. It consists of two components:

1. Somatic nerves
2. Autonomic (splanchnic or visceral) nerves.

The peripheral nerves include:

- 12 pairs of cranial nerves
- 31 pairs of spinal nerves
- Autonomic (splanchnic) nerves: Sympathetic and parasympathetic nerves.

The peripheral nerve contains the following nerve fibres:

1. *Somatic afferent (sensory) fibres* to carry sensory inputs from skin, bones, muscles, and joints to the CNS.
2. *Somatic efferent (motor) fibres* to carry motor impulses to the skeletal muscles.
3. *Visceral afferent (sensory) fibres* to carry input from the organ and blood vessels to the CNS.
4. *Visceral efferent (motor) fibres* to carry impulses from CNS to glands, smooth muscle of organs and blood vessels, and cardiac muscles.

Note: The bundle of nerve fibres in CNS is called *tract*.

Competencies:

AN68.1: Describe and identify multipolar and unipolar neurons, ganglia, peripheral nerve under the microscope.

AN68.3: Describe the ultrastructure of nervous tissue.

STRUCTURES OF PERIPHERAL NERVE

The peripheral nerve is a collection of many nerve fibres held together by connective tissue. The concept of nerve fibre is confusing as it does not mean a connective tissue fibre.

Nerve fibre indicates:

1. *Motor or efferent nerve fibres* are axons that carry impulses from CNS to muscle or glands. Cell bodies of motor neurons lie in CNS, especially in the grey matter of the spinal cord and brainstem.
2. *Afferent or sensory nerve fibres* are nerve processes that carry impulses or information toward CNS.
3. Nerve cell bodies of afferent fibres lie in the sensory ganglia.

Ganglion is a collection of nerve cell bodies outside the CNS.

Examples: Dorsal root ganglion, autonomic ganglion.

Basic Structure of Peripheral Nerve

(Flowchart 2.1, Fig. 2.1)

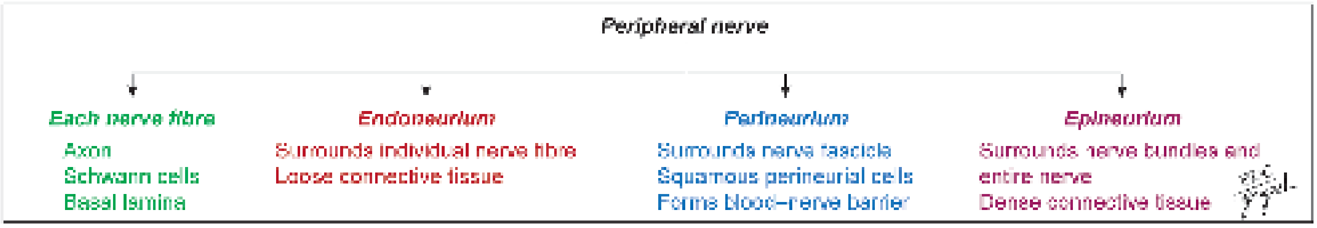
The *nerve fibre* with Schwann cells and basal lamina is the basic structural unit of the peripheral nerve. Each single *nerve fibre* is surrounded by a thin connective tissue called the *endoneurium*. The *endoneurium* consists of the loose connective tissue with collagen fibril, few fibroblasts, occasional mast cells, and macrophages.

Note: In peripheral nerve section, 90% of nuclei are of Schwann cells and only 10% belongs to connective tissue cells.

A group of nerve fibres forms a *nerve fascicle* or bundle. Each *nerve fascicle* is surrounded by a layer of specialized connective tissue called perineurium.

The *perineurium* is made-up of flattened (squamous) perineurial cells. They may be arranged in two or more perineurial cell layers and externally covered by a *basal lamina*. The perineurial cells are connected with each

Flowchart 2.1: Peripheral nerve


Peripheral nerve
Each nerve fibre
Axon
Schwann cells
Basal lamina
Endoneurium
Surrounds individual nerve fibre
Loose connective tissue
Perineurium
Surrounds nerve fascicle
Squamous perineurial cells
Forms blood–nerve barrier
Epineurium
Surrounds nerve bundles and entire nerve
Dense connective tissue

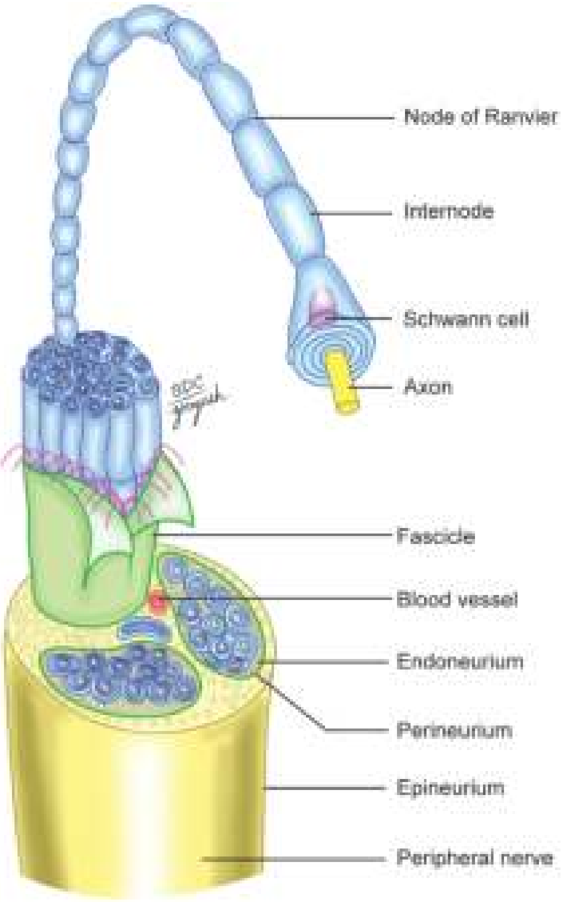

Node of Ranvier
Internode
Schwann cell
Axon
Fascicle
Blood vessel
Endoneurium
Perineurium
Epineurium
Peripheral nerve

Fig. 2.1: Structure of peripheral nerve

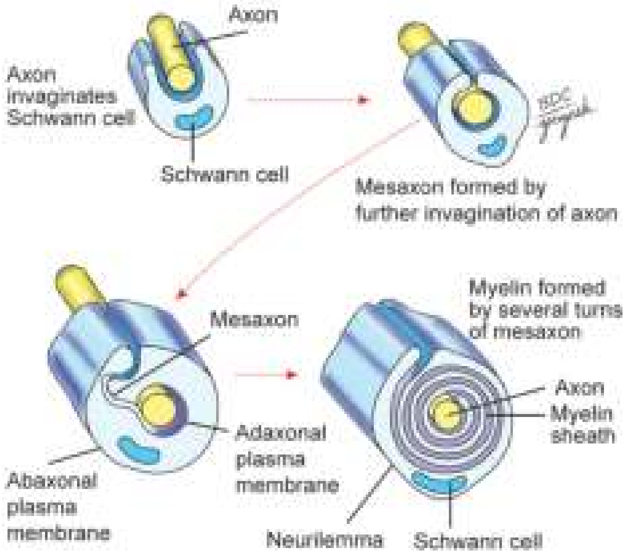

Axon
Axon invaginates Schwann cell
Schwann cell
Mesaxon formed by further invagination of axon
Mesaxon
Myelin formed by several turns of mesaxon
Axon
Myelin sheath
Adaxonal plasma membrane
Abaxonal plasma membrane
Neurilemma
Schwann cell

Fig. 2.2: Process of myelination

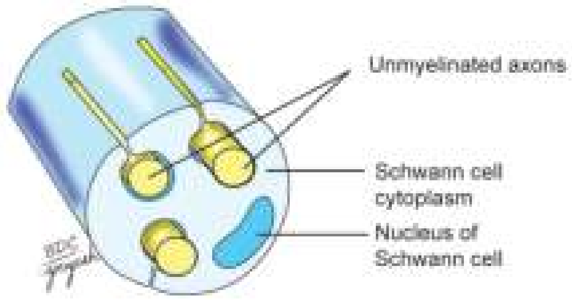

Unmyelinated axons
Schwann cell cytoplasm
Nucleus of Schwann cell

Fig. 2.3: Role of Schwann cell in the protection of nonmyelinated axon
Note: One Schwann cell surrounds multiple nonmyelinated nerve fibres.

other by tight junctions and hence, form a *blood–nerve barrier*.

Many fasciculi are held together by dense irregular connective tissue called epineurium. It surrounds entire peripheral nerve. It contains blood vessels that supply the nerve.

Note: Blood vessels (*vasa nervorum*) are present only in epineurium and perineurium. Endoneurium does not have blood vessels. Nerve fibres receive nutrition by diffusion through endoneurium.
H&E staining – axons, endoneurium, perineurium, and epineurium is stained. Myelin gives an empty appearance (Fig. 2.2). The osmium tetroxide is a special stain used for myelin. Myelin is washed away during preparation for *H&E stain*. Hence, osmium tetroxide staining method is used. In osmium tetroxide staining method, myelin sheath stains black (Fig. 2.3).

MYELIN SHEATH

The myelin is an insulating sheath surrounding the axons of myelinated nerve cells. Myelin is produced by oligodendrocytes in CNS and Schwann cells in PNS.

Formation of Myelin Sheath (Fig. 2.2)

In process of myelination, the axon initially lies in a groove of a Schwann cell. The cell membrane of Schwann cell is converted into three zones:

1. *Abaxonal plasma membrane* – exposed to an external environment
2. *Adaxonal/periaxonal plasma membrane* – lies in contact with axon
3. ***Mesaxon*** is a double membrane fold that connects abaxonal and adaxonal membranes.

The sheet-like extension of mesaxon surrounds axon spirally and cytoplasm of mesaxon gets squeezed.

Thus, it results in the formation of myelin sheath (lipid layer) around axon. Outside the myelin sheath, thin layer of cytoplasm of Schwann cell is present along with surrounding cell membrane of Schwann cells, now called ***neurilemma*** or *neurilemmal sheath*. The myelin consists of lipids (80%), proteins, and water.

Around a single axon, many Schwann cells form the myelin sheath. The gap between the segment of myelin and between adjacent Schwann cells is called ***nodes of Ranvier*** or ***incisura myelini***. These nodes increases the rate of nerve conduction by saltatory conduction.

The ***internode*** is a segment of myelin sheath between adjacent nodes of Ranvier. The thickness of myelin sheath depends on axon diameter of axon and not on Schwann cell. Myelin sheath thickness is regulated by neuregulin (NRG1) growth factor that is expressed on axolemma of the axon.

Functions of Myelin Sheath

1. Protection and physical support to axons
2. Insulation of axons
3. Increases nerve conduction by saltatory conduction
4. Neurilemmal sheath plays a major role in nerve regeneration.

Note:

- *Schmidt-Lanterman clefts*: These are the small pockets of cytoplasm in the inner layers of the myelin sheath. Usually, cytoplasm gets squeezed out of the myelin sheath during the wrapping of mesaxon around the axon.
- Nonmyelinated axons are covered by Schwann cells in PNS. Single Schwann cell is invaginated by multiple nonmyelinated axons.
- One Schwann cell can produce a myelin sheath around a small segment of one axon. One oligodendrocyte can produce a myelin sheath around many axons. Hence, the neurilemmal sheath is present only in the peripheral nervous system (cell membrane of Schwann cell) and not in CNS as a single oligodendrocyte does not cover one axon. Because of the absence of neurilemmal sheath in CNS, regeneration of neuron is not possible in CNS.
- A single Schwann cell protects many nonmyelinated axons (Fig. 2.3). The nerve fibres in the peripheral nerve may be myelinated or nonmyelinated, most of the fibres in the peripheral nerve are myelinated.
- Nonmyelinated fibres include fine sensory nerve fibres and postganglionic autonomic fibres. These are called *type C fibres*.

CLINICAL NEUROANATOMY

Enuresis (bed-wetting). It is observed in the first 3–6 years of life. It occurs up to the completion of myelination of corticospinal tract fibres that control the emptying of the urinary bladder. *Embryological basis*: The myelination begins before birth and continues for a few years after birth. Enuresis is normal in infants.

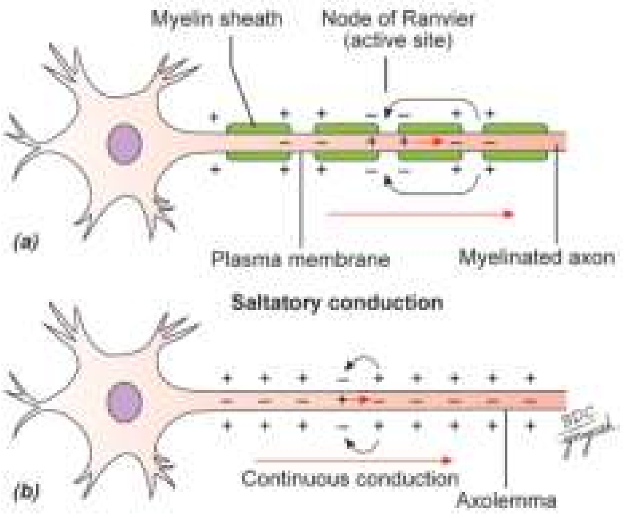
CONDUCTION OF ACTION POTENTIAL

The ionic concentration within the neuron and extracellular fluid creates *resting membrane potential* across the neuronal plasma membrane (RMP). At resting membrane potential, the neuronal plasma membrane is polarized. Resting membrane potential is always negative (–70 mV).

The resting membrane potential is negative because of the high concentration of cations (for example, Na^+ ions) outside the nerve fibres in the extracellular fluid.

Action potential is a sequential change in membrane potential that develops on activation or stimulation of the nerve cell. The rise in membrane potential soon comes back to resting membrane potential. It involves two phases:

1. ***Depolarization*** – increase in membrane potential up to +40 mV
2. ***Repolarization*** – decrease in or restoration of membrane potential.



Figs 2.4a and b: Conduction of action potential along an axon: (a) In myelinated axon and (b) in nonmyelinated axon

The action potential is generated at one point of the neuronal plasma membrane, and it propagates across this membrane (Figs 2.4a and b). The speed of conduction of action potential depends on the myelination of the nerve fibres. The thickness of myelin is directly proportional to the conduction of action potential.

Saltatory conduction (*saltare* = to leap in Latin) is jumping conduction of action potential from one node of Ranvier to other nodes of Ranvier. In thick myelinated motor fibres (alpha fibres), the speed of conduction is very high (70–120 meters per second).

CLASSIFICATION OF NERVE FIBRES

Based on the diameter of the nerve fibres, they are grouped as follows (Table 2.1):

Group A: Highly myelinated fibres
Group B: Thinly myelinated fibres (up to 3 μm thick)
Group C: Nonmyelinated fibres (about 0.2–1.5 μm thick).

CLINICAL NEUROANATOMY

Nerve injuries: Based on the severity of the damage, nerve injuries are classified as:

1. *Neurotmesis* – both axon and myelin sheath damaged
2. *Axonotmesis* – only axon is damaged, myelin sheath is intact
3. *Neuropraxia* – both axon and myelin sheath are preserved.

- Nerve regeneration occurs in the peripheral nerve in case of ***neuropraxia*** and ***axonotmesis***, but in case of *neurotmesis*, nerve regeneration does not occur.

Nerve degeneration and regeneration: The injury to the axon with myelin sheath follows two events:

1. Degeneration of nerve fibre
2. Regeneration of nerve fibre.

Rate of nerve regeneration/growth is 3.5 to 4.5 mm per day. A proper nutrition is essential for faster nerve regeneration.

TABLE 2.1: Classification of peripheral nerve fibres

Type of fibre	*Example*	*Maximum diameter*	*Myelin*	*Conduction velocity (m/s)*
Group A fibres				
Afferent (sensory) fibres				
Type Ia	Annulospiral endings of muscle spindle	20 μm	Present	18–120
Type Ib	Golgi tendon	20 μm	Present	80–120
Type II	Flower-spray ending in muscle spindle Cutaneous mechanoreceptors (touch, pressure)	12 μm	Present	33–75
Type III	Free nerve endings for pain and temperature	5 μm	Thin	30
Efferent (motor) fibres				
Alpha (α) motor neurons	Supply extrafusal muscle fibres	20 μm	Present	120
Beta (β) motor neurons	Supply extrafusal fibres and muscle spindle	12 μm	Present	70
Gamma (γ) motor neurons	Supply intrafusal muscle fibres	8 μm	Present	24
Group B fibres	Preganglionic fibres	5 μm	Present	15
Group C fibres	Postganglionic autonomic fibres	1.5 μm	Absent	2

Degeneration of nerve fibre: These are the changes that occur in the nerve cell following the injury. These include changes in the nerve cell body and changes in the nerve fibre (Fig. 2.5).

- *Changes in nerve fibre*: These include:
  1. *Wallerian degeneration*: These are changes in the distal segment. It includes disintegration of myelin and degeneration of nerve fibres.
  2. Degeneration of proximal segment up to the nearest node of Ranvier.
- *Changes in the nerve cell body*: Due to loss of neural activity after injury, the cell body undergoes the following changes:
  1. Chromatolysis – disintegration of Nissl bodies
  2. Cell swelling
  3. Nucleus shifts to an eccentric position.

Regeneration of nerve fibre: The regeneration of nerve fibres is a very slow process. It begins after two weeks after injury. It involves (Fig. 2.5):

1. In the process of regeneration, macrophages remove the degenerated debris by phagocytosis.
2. Schwann cell proliferation: The Schwann cells proliferate and fill the empty space created by disintegration of axon and the myelin. Schwann cells also fill the gap between proximal and distal segments of axon.
3. Axonal growth: The ends of the axon give rise to multiple sprouts that enter the *endoneurial tube* of proliferated Schwann cells.
4. Elongation of axon: One of the axonal sprouts continues elongation under the guidance of Schwann cells to reach the end organ.
5. Regeneration of myelin: Surrounding Schwann cells reform the myelin sheath to restore the function completely.

Neuroma is a benign tumour. Sometimes, if the distance between the cut ends of nerve fibres is more, then the gap is filled with fibrous tissue which contains growing axonal sprouts. This mass forms neuroma. It is painful.

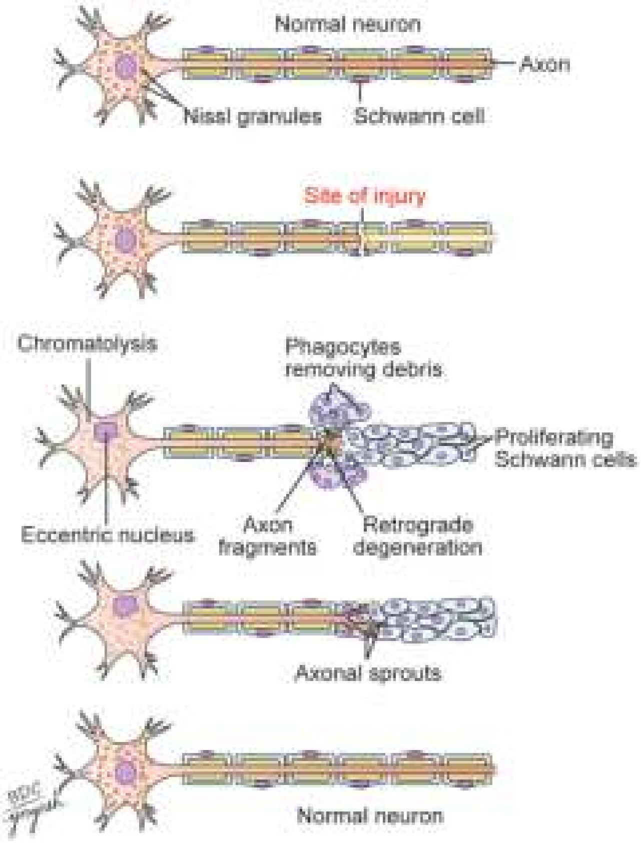


Fig. 2.5: Degeneration and regeneration of a nerve fibre (Wallerian degeneration)

GANGLIA

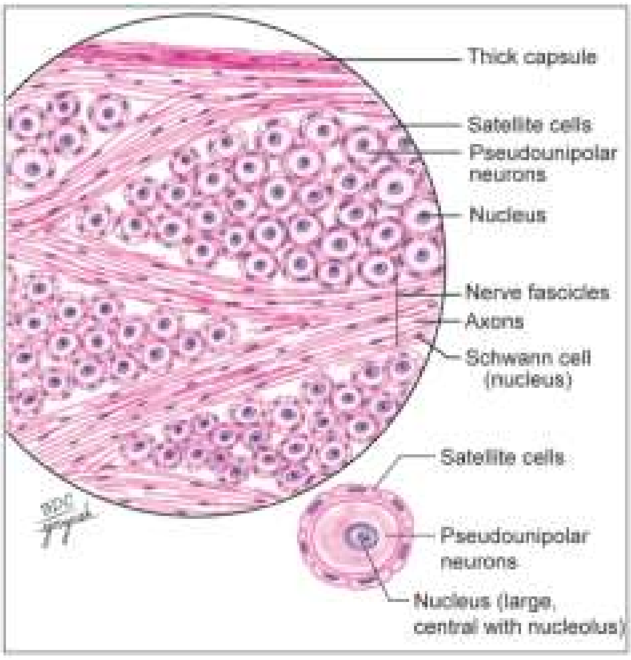
The ganglion is the aggregation of the cell bodies of neurons outside the central nervous system.

Ganglia are of two types: Sensory and autonomic.

Sensory Ganglia

The sensory ganglia are present just outside the CNS. The neurons of sensory ganglia carry impulses toward CNS (Plate 2.1, Flowchart 2.2).

Plate 2.1: Histology of dorsal root/sensory ganglion


Thick capsule
Satellite cells
Pseudounipolar neurons
Nucleus
Nerve fascicles
Axons
Schwann cell (nucleus)
Satellite cells
Pseudounipolar neurons
Nucleus (large, central with nucleolus)

Examples:

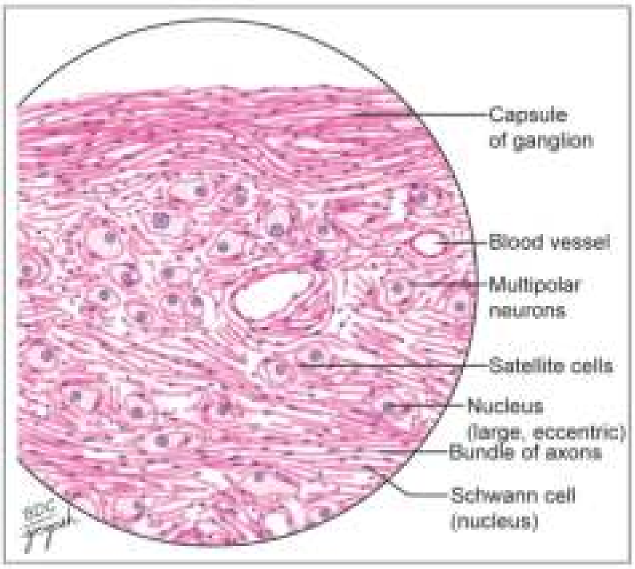
1. Dorsal root ganglia of spinal nerves
2. Sensory ganglia of cranial nerves: Trigeminal, facial, vestibulocochlear, glossopharyngeal, and vagus nerves.

Structure of Sensory Ganglia

The sensory ganglia have *pseudounipolar neurons* (except vestibulocochlear ganglia that has bipolar neurons). These neurons have a peripheral process that carries information from the sensory receptor and a central process that passes received information to CNS.

A section of sensory ganglia shows *large neurons that are present in groups*, mostly at the periphery of ganglia. The nuclei of neurons are large, vesicular, and *centrally placed*. The group of neurons are separated by bundles of myelinated nerve fibres. Each neuronal body is surrounded by a *complete capsule* of satellite or capsular cells which are flattened cells (low cuboidal). The ganglion is covered by a fine connective tissue capsule.

Plate 2.2: Histology of autonomic/sympathetic ganglion


Capsule of ganglion
Blood vessel
Multipolar neurons
Satellite cells
Nucleus (large, eccentric)
Bundle of axons
Schwann cell (nucleus)

Autonomic Ganglia

The autonomic ganglia supply smooth muscles and glands. The autonomic nervous system shows two neurons (Plate 2.2, Flowchart 2.2):

1. *Preganglionic neuron*: It lies in CNS and its axons extend from CNS up to autonomic ganglia.
2. *Postganglionic neuron*: It lies in autonomic ganglia and its axon supplies smooth muscle cells and glands.

Examples:

1. *Sympathetic ganglia*: Sympathetic trunk, paravertebral ganglia (celiac, superior mesenteric, inferior mesenteric, and aorticorenal ganglia), and adrenal medulla.
2. *Parasympathetic ganglia*: Ciliary ganglion, submandibular ganglion, otic ganglion, pterygopalatine ganglion, and terminal ganglia that lie near the organs.

Structure of Autonomic Ganglia

Usually, the sympathetic ganglion is easy to obtain and sufficiently large for teaching purposes; hence, its slide (section) is given for practical demonstration as a prototype of autonomic ganglia. The autonomic ganglia are smaller than the sensory ganglia.

Flowchart 2.2: Ganglia

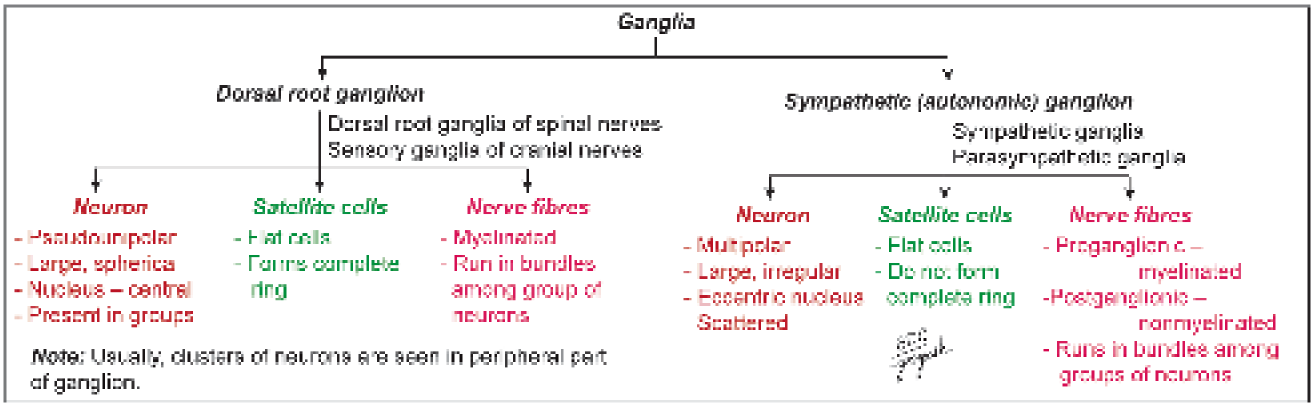

Ganglia
Dorsal root ganglion
Dorsal root ganglia of spinal nerves
Sensory ganglia of cranial nerves
Neuron
- Pseudounipolar
- Large, spherical
- Nucleus – central
- Present in groups
Satellite cells
- Flat cells
- Forms complete ring
Nerve fibres
- Myelinated
- Run in bundles among group of neurons
Note: Usually, clusters of neurons are seen in peripheral part of ganglion.
Sympathetic (autonomic) ganglion
Sympathetic ganglia
Parasympathetic ganglia
Neuron
- Multipolar
- Large, irregular
- Eccentric nucleus
Scattered
Satellite cells
- Flat cells
- Do not form complete ring
Nerve fibres
- Preganglionic – myelinated
- Postganglionic – nonmyelinated
- Runs in bundles among groups of neurons

TABLE 2.2: Differences between sensory and autonomic ganglia

Criteria	*Sensory (dorsal root) ganglion*	*Autonomic (sympathetic) ganglion*
Neuron	Pseudounipolar	Multipolar
Neuron-body shape	Large spherical	Small irregular
Types of neurons	Sensory	Postganglionic autonomic/sympathetic neuron
Nucleus	Large, vesicular, centrally placed	Large, vesicular, eccentrically placed
Satellite cells	Complete ring around the neuronal body	Few satellite cells, do not form a complete ring around the neuronal body
Neuronal groups	Neurons are present in groups (clusters)	Neurons are scattered
Nerve fibres	Nerve fibres are present in bundles that separate clusters of neurons	Nerve fibres are present between scattered neurons

The *multipolar postganglionic neurons* of autonomic ganglia are scattered throughout the ganglion. These neurons are separated from each other by discrete bundles of nerve fibres (nonmyelinated and thin). The *nuclei* of neurons are large, pale-staining with the prominent nucleolus, and *eccentrically placed* in the cytoplasm. Few satellite cells are seen to surround each nerve cell body, but these cells *do not form a complete capsule*. The ganglion is surrounded by a connective tissue capsule.

As postganglionic autonomic neurons synthesize catecholamines, Nissl granules are prominently seen in their cytoplasm. Silver staining is useful for better visualization of processes of neurons.

The difference between sensory and autonomic ganglia are listed in Table 2.2.

CLINICAL NEUROANATOMY

- *Peripheral neuropathy:* It is a disease or injury that affects the functions of the peripheral nerve. It may have acute (rapid) onset or chronic (slower onset) progressive course. The signs and symptoms depend on the nerves involved. It may be:
  1. Mononeuropathy – involves a single nerve
  2. Polyneuropathy – involves many nerves

  It may result in the numbness, paralysis, imbalance, gait, impairment, and muscle atrophy and burning, itching, tingling, or pricking sensation due to nerve irritation.
- ***Radiculopathy*** involves compression of the nerve root (typical spinal nerve) in case of spondylitis or disc prolapse.
- **Entrapment syndrome** results due to compression of peripheral nerve in a narrow passage. For example, compression of the median nerve in the carpal tunnel.
- ***Multiple sclerosis*** (*encephalomyelitis disseminate*) is an autoimmune disease that results in degeneration of the myelin sheath. It causes numbness, impairment of muscular coordination, blurred vision, and severe fatigue due to impaired nerve conduction.

Facts to Remember

- Myelin is produced by oligodendrocytes in CNS and Schwann cells in PNS.
- Schmidt-Lanterman clefts are the small pockets of cytoplasm in the inner layers of the myelin sheath.
- One Schwann cell can produce a myelin sheath around a small segment of one axon. One oligodendrocyte can produce a myelin sheath around many axons.
- Because of the absence of neurilemmal sheath in CNS, regeneration of neuron is not possible in CNS.
- Thickness of myelin is directly proportional to the conduction of action potential.
- Sensory ganglia have pseudounipolar neurons (except vestibulocochlear ganglia that has bipolar neurons)

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1. Further reading
2. Viva voce questions

Chapter

3

Receptors

The peripheral endings of sensory (afferent/ascending) and motor (efferent/descending) nerves are called receptors.

Classification of Receptors

The receptors are classified into various groups based on:

1. ***Functional basis:*** Exteroceptors, proprioceptors, and interoceptors.
2. ***Stimulus that activates them:*** For example, mechanoreceptors, chemoreceptors, and so on (Table 3.1).
3. ***Anatomical basis:*** Encapsulated and nonencapsulated.
4. ***Location:*** Cutaneous receptors, muscle receptors, tendon receptors, joint receptors.

Functional Classification of Receptors

1. ***Exteroceptors*** are receptors that get stimulated by the stimuli from outside the body. They are located in the skin and called cutaneous receptors.
2. ***Proprioceptors*** are receptors that receive stimuli of the position of body parts such as joints, muscles, and tendons.
3. ***Interoceptors*** are receptors that receive information from blood vessels (increase or decrease in blood pressure) and from viscera (expansion, collapse, and so on).

Anatomical Classification of Receptors

Anatomically, the sensory receptors are classified as (Table 3.2, Fig. 3.1):

- A. Encapsulated receptors:
  1. Meissner's corpuscles
  2. Pacinian corpuscles
  3. End bulb of Krause
  4. Ruffini's corpuscles.
- B. Nonencapsulated receptors:
  1. Free nerve endings
  2. Peritrichial or root hair plexus
  3. Merkel disc.

SENSORY AFFERENT RECEPTORS

The peripheral endings of afferent fibres which receive impulses are known as receptors.

TABLE 3.1: Type of receptors based on the stimuli

Receptor type	*Stimulus*
Mechanoreceptors	Mechanical deformation
Chemoreceptors	Chemical change (such as pH)
Thermoreceptors	Change in temperature
Nociceptors	Damaged tissue (induces pain and discomfort)
Osmoreceptors	Change in osmotic pressure

TABLE 3.2: Receptors and their activating stimulus

Receptor	*Stimulus*
Free nerve endings	Fine touch, heat, cold, pain sensation, hair-movement senses
Merkel disc	Mechanoreceptors
Meissner's corpuscles	Light touch
Pacinian corpuscles	Deep pressure, vibration
End bulb of Krause	Cold, temperature
Ruffini's corpuscles	Stretch, torque sensation
Peritrichial or root hair plexus	Fine touch

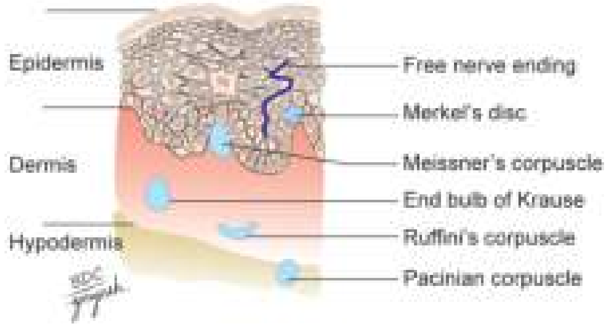


Fig. 3.1: Location of receptors in the skin

Nonencapsulated Receptors

Here the sensory nerve endings do not show any particular specialisation of structure and are directly applied to the tissue cells or may lie freely in the extracellular spaces.

1. ***Free nerve endings:*** Sensory nerve endings which repeatedly form plexuses or terminate with fewer branches constitute free nerve endings. Such types of endings are found in connective tissue, dermis of skin, fasciae, tendons, ligaments, joints, capsules, peritoneum, perichondrium and sheaths of blood vessels. These are particularly numerous in relation to hair follicles.

   These endings respond to temperature, touch and stretch. So these are thermoreceptors and mechanoreceptors. They respond to pain also (Fig. 3.2).
2. ***Merkel (disc-shaped) endings:*** The nerve fibres of these structures expand into a disc applied closely to the base of a specialised non-nervous cell (the Merkel cell) which is inserted into the basal cells of epithelium of the epidermis. These are also found around apical ends of certain hair follicles. These are responsive to pressure sensations.

Encapsulated Nerve Endings

These are special end organs. These have one feature in common that is the termination of nerve is enveloped by a capsule. These may be present in dermis, joints, muscles and tendons (Fig. 3.2).

1. ***Tactile corpuscles of Meissner:*** These are found in the dermal papillae of skin of hand, feet, front of forearm, lips and mucous membrane of tip of tongue. They are cylindrical in shape with long axis perpendicular to deep surface of epidermis and are about 80 µm long and 30 µm broad. Each corpuscle consists of a capsule with central core. The capsule consists of elastic fibres oriented along the long axis of corpuscle and interspersed with fibrocytes. The elastic fibres anchor the corpuscle to the epidermis. The capsule contains number of lamellae of flattened cells with associated basement membrane. The core of corpuscle is supplied by several myelinated nerve fibres and a few unmyelinated nerve fibres. These are responsible for touch.

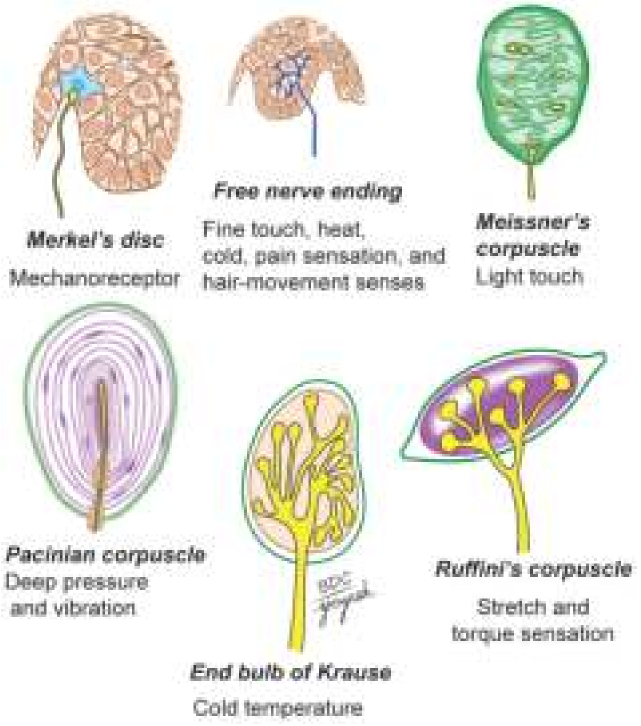


Fig. 3.2: Structure of the receptors located in the skin

2. ***Lamellated (Pacinian) corpuscles:*** These are found in subcutaneous tissue on the palmar aspects of hand, plantar aspect of foot and digits, in the genital organs of both sexes, arms, nipple, neck and in mesentery. These are relatively big in comparison to other end organs and are about 2 mm in length and 100 to 200 µm in width.

   The centre of the core generally contains a single nerve fibre, the end of which is expanded into a bulb. Lamellated corpuscles are pressure receptors.
3. ***Ruffini's corpuscles:*** These are also encapsulated nerve endings. They contain collagen bundles which emerge at each end of the thin perineurial capsule. They are slowly adapting and give a sustained response when the skin is stretched in their long axes. These occupy deep dermis and respond when heavy objects are gripped.

   Note: Functional application: The encapsulated nerve endings and tactile menisci are all mechanoreceptors. Meissner's and Pacinian corpuscles are rapidly adapting tactile menisci. In medical practice, five modalities are easily tested. These are deep touch, vibration, light touch, temperature (warm or cold) and pain. Ruffini's corpuscles are slowly adapting.
4. ***Krause's end bulb:*** Mainly found in the mucocutaneous regions, e.g. lips and external genitalia. The bulb is spheroidal in shape, about 50 µm in diameter. Its capsule is continuous with the endoneurium. The nerve fibres branch into the bulb. It probably receives thermal impulses.

Joints, Muscles and Tendons

The afferent endings are proprioceptors and furnish the central nervous system with information required for the performance of properly coordinated movements. In addition, proprioceptive information reaches consciousness so that there is awareness of the position of body parts and of their movements. Pain arising in muscles, tendons and bones is detected by free nerve endings in connective tissue. These are known as nociceptive fibres. The receptors in tendons and muscles are: neurotendinous spindle of Golgi and neuromuscular spindle.

Neurotendinous Spindle of Golgi

The *Golgi tendon organ* (*GTO*) is a fusiform-shaped receptor located at sites where muscle fibres insert into the tendon (Fig. 3.3). It consists of interlacing intrafusal collagen bundles enclosed in connective tissue capsule. It is innervated by type A sensory fibres. Each nerve fibre pierces the capsule and branches into numerous terminals that are interposed among the intrafusal collagen bundles.

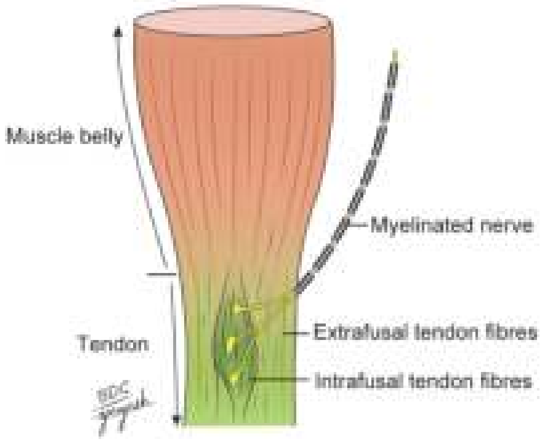


Fig. 3.3: Golgi tendon organ (a neurotendinous spindle)

Function

Golgi tendon organ monitors the tension produced during muscle contraction. It inhibits the activity of α-motor neuron that produces muscle contraction (through interneurons).

Neuromuscular Spindles

The muscle (neuromuscular) spindle is a spindle-shaped sensory end organ of skeletal muscles (Plate 3.1).
Length: 5–10 mm
Diameter: 100 µm.

Structure

It consists of capsules, sensory neuron, gamma motor neurons, and intrafusal muscle fibres. The muscle spindle is enclosed within fusiform connective tissue fibres.

It has ***intrafusal muscle fibres*** that are enclosed within the capsule. The extrafusal fibres form the main bulk of the muscle.

There are two types of intrafusal fibres:

1. *Nuclear bag fibres*: Many nuclei are located in the middle of the fibres.
2. *Nuclear chain fibres*: Nuclei are arranged in a single row.

Nuclear bag fibres are long and extend outside the capsule up to the endomysium of adjacent extrafusal fibres.

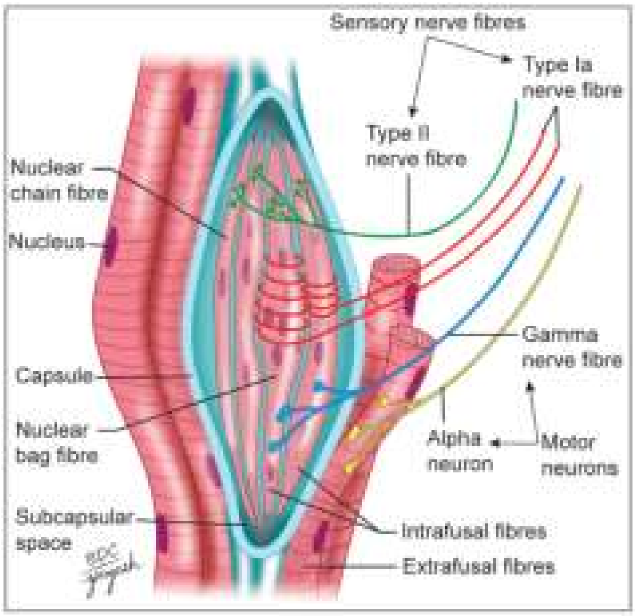
Nerve supply of muscle spindle:

- Muscle spindle is supplied by gamma motor neurons and sensation is carried by sensory afferent nerve fibres (type Ia and II). Extrafusal (main muscle) fibres are supplied by alpha motor neurons.
- Type Ia fibres have annulospiral nerve endings that surround the central area of the nuclear chain and bag fibres.
- Type II fibres have floral spray endings that are present in the peripheral part of bag fibres.
- The sensory neurons get stimulated on the stretching of muscle fibres.

Functions

During muscle contraction, stretching of muscle spindle stimulates sensory nerve fibres (type Ia and type II). These sensory fibres provide inputs to the CNS about muscle stretch and help to modulate the activity of motor neurons supplying the same muscle.

Plate 3.1: Muscle spindle



CLINICAL NEUROANATOMY

***Myotatic* or *stretch reflex*:** Elongation of the spindle on stretching the skeletal muscle produces reflex rapid contraction of the muscle. This is called the *stretch reflex*. *Components*: Muscle stretch → stimulation of type I and type II sensory nerve fibres of muscle spindle → synapse with alpha (α) motor neuron → skeletal muscle contraction (Plate 3.1).

EFFECTOR NERVE ENDINGS

The effector nerve endings or motor efferent endings controls the activity of the skeletal or smooth muscles.

Somatic Effectors

The somatic effectors are the terminals of myelinated motor neurons. These are lower motor neurons.

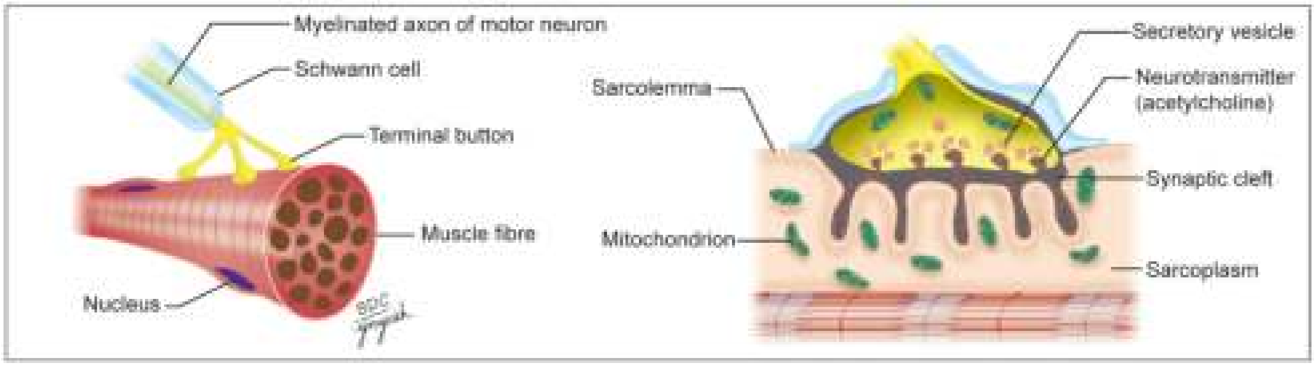
Motor Innervation of Skeletal Muscle

The myoneural junctions or motor end plates on extrafusal and intrafusal fibres of skeletal/striated muscles are synapse-like structure with two components, i.e. the ending of a motor nerve fibre and subjacent part of the muscle.

The number of muscle fibres in a motor unit (number of muscle fibres supplied by a single alpha motor neuron) varies from one to several hundred depending upon the size and function of a muscle.

A large **motor unit** in which a single neuron supplies many muscle fibres, is adequate for the function of muscles such as those of trunk and proximal portion of limbs. However, in extraocular and intrinsic muscles

Plate 3.2: Neuromuscular junction



of hand which function with precision, the motor unit includes only a few muscle fibres.

Each branch of nerve fibre gives up its myelin sheath on approaching a muscle fibre and ends as several branchlets that constitute the neural component of **end plate** (Plate 3.2).

In the majority of muscles, the terminals of the nerve end in a small localised area of muscle fibre forming a so-called motor end plate. In this region, the sarcoplasm contains many nuclei rich in mitochondria and has granular appearance. This region of sarcoplasm is known as soleplate. There is an interval of 20–50 µm, constituting a synaptic cleft between surface of nerve terminal and that of muscle fibre. The sarcolemma of muscle fibre has a wavy outline where they oppose the nerve terminal, with irregularities being known as junctional folds. Axon terminal in this region is rich in mitochondria and contains vesicles similar to those seen in the region of synapse. There is no protoplasmic continuity between the axoplasm and sarcoplasm.

The vesicles in axoplasm contain the neurotransmitter acetylcholine that is released when nervous impulse reaches myoneural junction. Acetylcholine creates a wave of depolarisation in the sarcolemma resulting in contraction of muscle fibres. Thereafter, acetylcholine is quickly destroyed by an enzyme called cholinesterase.

Innervation of Smooth Muscles and Glands

The contact between nerve ending and smooth muscle is not as close as in skeletal muscle. Axon terminal contains vesicles. In most cases of sympathetic terminals, these vesicles contain adrenaline or noradrenaline. In case of parasympathetic terminals, they contain acetylcholine. Similarly, the nonmyelinated nerve endings come in contact with the secretory cells.

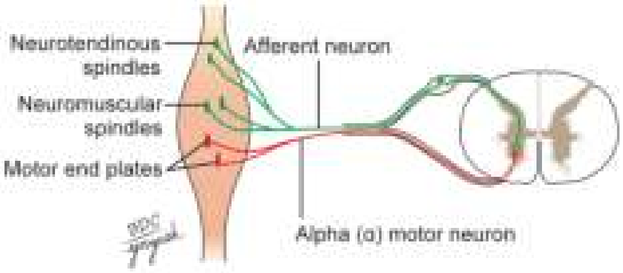


Fig. 3.4: Stretch reflex. A simple reflex arc consisting of an afferent neuron that is arising from neuromuscular spindle or neurotendinous spindle and an efferent alpha motor neuron stimulating extrafusal muscle fibres

CLINICAL NEUROANATOMY

- ***Myasthenia gravis***: It is a consequence of autoimmune destruction of nicotinic postsynaptic receptors for acetylcholine. Thymus abnormality occurs in 80% of patients.

  Clinical features: Limb and trunk: Weakness of neck muscles resulting in rolling of head. Proximal limb muscles are preferentially affected. Limb reflexes are hyperactive. Muscle wasting occurs in 15% cases.

  Diagnosis: Acetylcholine receptor antibodies are detected in majority of patients.
- ***Myotatic or stretch reflex***: Elongation of the spindle on stretching the skeletal muscle produces reflex rapid contraction of the muscle. This is called the stretch reflex.

  Components: Muscle stretch → stimulation of type I and type II sensory nerve fibres of muscle spindle → synapse with alpha motor neuron → skeletal muscle contraction (Fig. 3.4).

Facts to Remember

- Meissner's corpuscles – Light touch
- Pacinian corpuscles – Deep pressure, vibration
- End bulb of Krause – Cold, temperature
- Ruffini's corpuscles – Stretch, torque sensation
- Free nerve endings – Fine touch, heat, cold, pain sensation, hair-movement senses
- Merkel disc – Mechanoreceptors
- Peritrichial or root – Fine touch hair plexus

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1. Further reading
2. Viva voce questions

Chapter

4

Meninges of the Brain and Cerebrospinal Fluid

The brain is a very important delicate organ. It is protected by the following coverings.

1. Bony covering of the cranium
2. Three membranous coverings (meninges):
   a. Outer dura mater (pachymeninx)
   b. Middle arachnoid mater
   c. Inner pia mater.

   Note: The arachnoid and pia are together known as the leptomeninges.

   [*Mnemonics*: ***PAD:*** **P** – Pia mater; **A** – Arachnoid mater; **D** – Dura mater]
3. The spaces in relation to meninges are:
   a. Extradural/epidural
   b. Subdural
   c. Subarachnoid
4. The cerebrospinal fluid (CSF) fills the space between the arachnoid and the pia maters (subarachnoid space) and acts as a water cushion.

Competency:
AN56.1 Describe and identify various layers of meninges with its extent and modifications.

MENINGES

DURA MATER

The cerebral or cranial dura mater is the thickest, toughest, and outermost fibrous covering of brain (*dura* = hard, *mater* = mother).

The cerebral dura mater is made up of two layers: Outer endosteal and inner meningeal layers, and enclosing the cranial venous sinuses between these two.

The ***endosteal layer*** is attached to the inner surfaces of the cranial bones and is continuous through the sutural ligaments, and around the margins of the foramina with the periosteum on the external surface of the cranium. It provides *sheaths* for the cranial nerves, the sheaths fuse with the epineurium outside the skull.

The ***meningeal layer*** forms four folds:

1. Falx cerebri
2. Tentorium cerebelli
3. Falx cerebelli
4. Diaphragma sellae.

These folds divide the cranial cavity into intercommunicating compartments for different parts of the brain (Table 4.1, Figs 4.1 and 4.2). The meningeal layer is continuous with the ***spinal dura*** mater.

The details of cerebral dura mater are described in Chapter 12, Volume 3.

Folds of Dura Mater

Falx Cerebri

The falx cerebri is a large sickle-shaped fold of dura mater occupying the median longitudinal fissure between the two cerebral hemispheres (Plate 4.1).

Tentorium Cerebelli

The tentorium cerebelli is a tent-shaped fold of dura mater, forming the roof of the posterior cranial fossa. It separates the cerebellum from the occipital lobes of the cerebrum, and broadly divides the cranial cavity into supratentorial and infratentorial compartments. The infratentorial compartment is the posterior cranial fossa containing the hindbrain and the lower part of the midbrain.

Its anterior free margin *forms the* U-shaped ***tentorial notch*** which is occupied by the midbrain and the anterior part of the superior vermis.

Falx Cerebelli

The falx cerebelli is a small sickle-shaped fold of dura mater projecting forwards into the posterior cerebellar notch.

Diaphragma Sellae

The diaphragma sellae is a small circular, horizontal fold of dura mater forming the roof of the hypophyseal fossa. The diaphragma has a ***central aperture*** through which the stalk of the hypophysis cerebri passes.

Blood Supply

The outer layer is richly vascular. It is supplied by the middle meningeal, anterior ethmoidal, posterior ethmoidal, ophthalmic, accessory meningeal, internal carotid, ascending pharyngeal artery, vertebral, and occipital arteries.

TABLE 4.1: The meningeal layer sends inward following folds of dura mater

Folds	*Shape*	*Attachments*	*Venous sinuses enclosed*
Falx cerebri	Sickle-shaped, separates the right from left cerebral hemisphere	Superior, convex margins are attached to sides of the groove lodging the superior sagittal sinus Inferior concave margin is free Anterior attachment is to crista galli and frontal crest Posterior attachment is to upper surface of cerebelli tentorium	Superior sagittal sinus Inferior sagittal sinus Straight sinus
Tentorium cerebelli	Tent-shaped, separates the cerebral hemispheres from hindbrain and lower part of midbrain Lifts off the weight of occipital lobes from the cerebellum	Has a free anterior margin. Its ends are attached to anterior clinoid processes Rest is free and concave Posterior margin is attached to the lips of groove containing transverse sinuses, superior petrosal sinuses and to posterior clinoid processes	Transverse sinuses, Superior petrosal sinuses
Falx cerebelli	Small sickle-shaped fold partly separating two cerebellar hemispheres	Base is attached to posterior part of inferior surface of tentorium cerebelli Apex reaches till foramen magnum	Occipital sinus
Diaphragma sellae	Small horizontal fold	Anterior attachment is to tuberculum sellae Posterior attachment is to dorsum sellae; laterally continuous with dura mater of middle cranial fossa	Anterior and posterior intercavernous sinuses

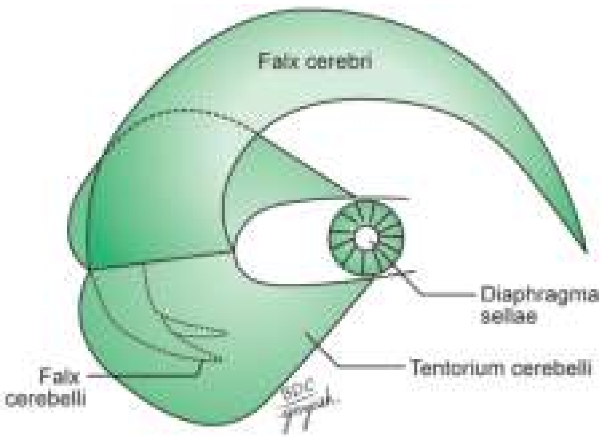


Fig. 4.1: Various folds of meningeal layer of dura mater

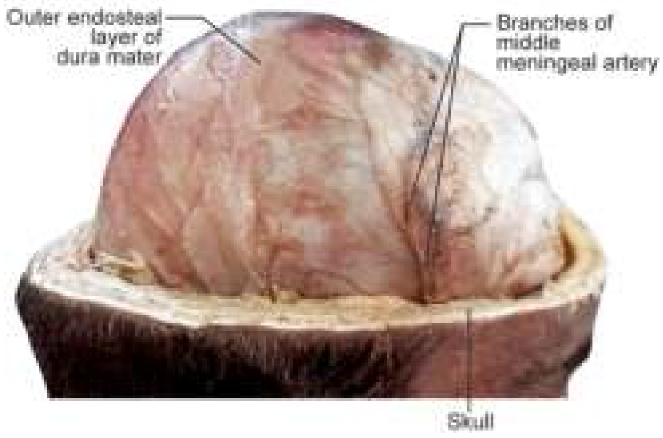

Outer endosteal layer of dura mater
Branches of middle meningeal artery
Skull

Fig. 4.2: Endosteal layer of dura mater

DISSECTION

Cut through the fused endosteum and dura mater on the ventral aspect of brain from the inferolateral borders extending along the superolateral margin. Pull upwards the endosteum along with the fold of dura mater present between the adjacent medial surfaces of cerebral hemispheres, extending from the frontal lobe till the occipital lobe. This is falx cerebri. Pull backwards a similar but much smaller fold between two adjacent lobes of cerebellum—the falx cerebelli.

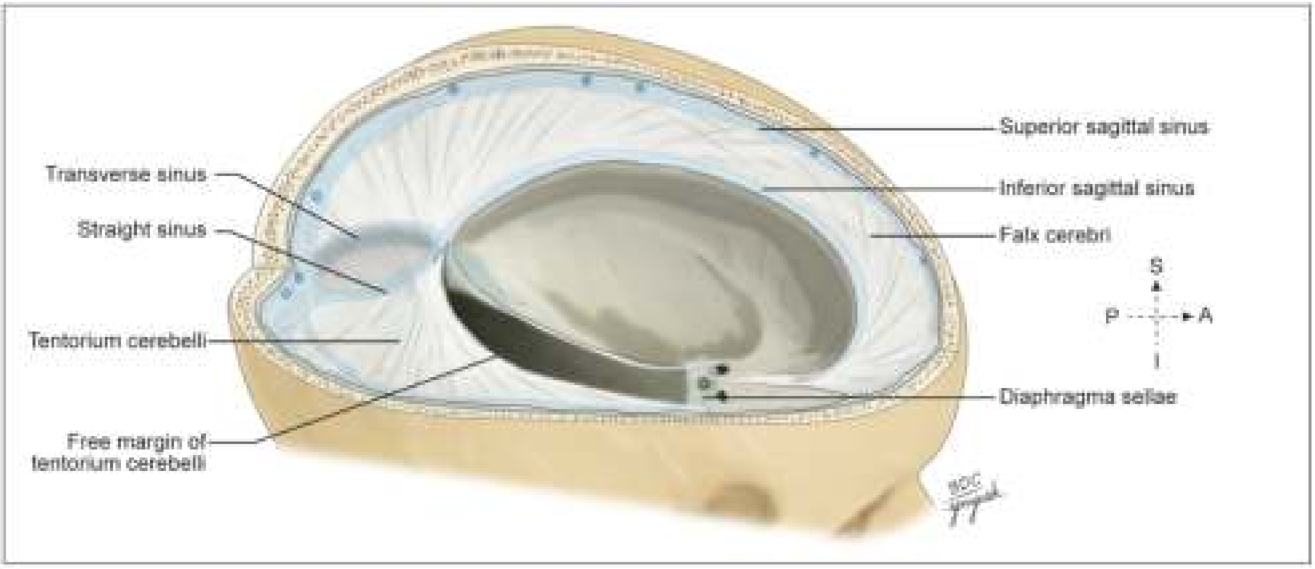
Separating the cerebrum and the cerebellum is another fold of dura mater called the tentorium cerebelli. Pull it on a horizontal plane. Thus, the fused endosteum and dura mater get separated from the underlying subarachnoid mater, pia mater and the brain.

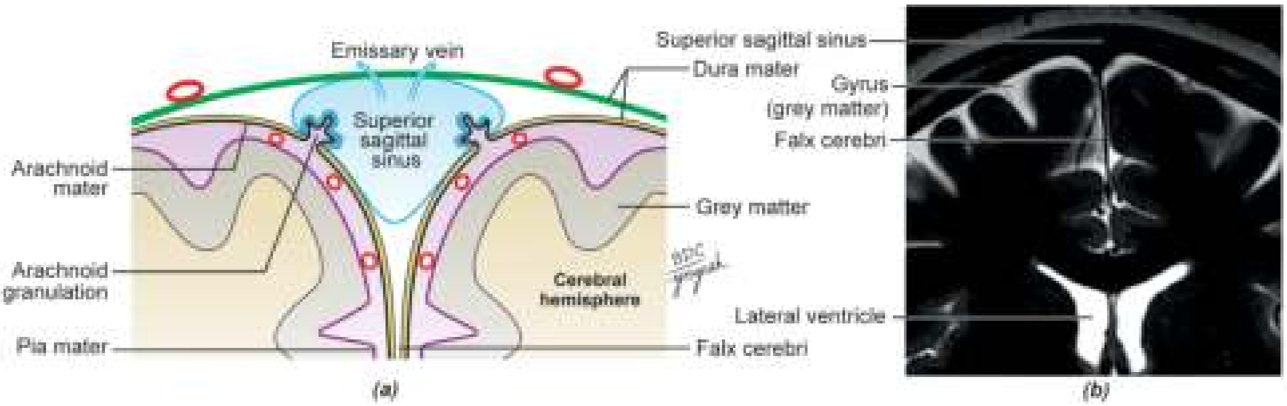
Identify various venous sinuses between the endosteum and folds of dura mater. Underneath the dura mater and separated by a flimsy subdural space is the cobweb-like arachnoid mater. It is separated from the underlying pia mater by the subarachnoid space, containing cerebrospinal fluid and blood vessels of the brain. Cranial nerves also pass through this space. Near the superior sagittal sinus, arachnoid mater forms arachnoid villi. The subarachnoid space is dilated around the brainstem and at the base of the brain forming the subarachnoid cisterns.

ARACHNOID MATER

The arachnoid (Latin *cobweb-like*) mater is a thin transparent membrane that loosely surrounds the brain *without* dipping into many of its sulci (Figs 4.3a and b

Plate 4.1: Dural folds and dural venous sinuses enclosed within them, viewed from superolateral aspect


Transverse sinus
Straight sinus
Tentorium cerebelli
Free margin of tentorium cerebelli
Superior sagittal sinus
Inferior sagittal sinus
Falx cerebri
S
P
A
I
Diaphragma sellae
BDC


Emissary vein
Superior sagittal sinus
Arachnoid mater
Arachnoid granulation
Pia mater
Cerebral hemisphere
BDC
Superior sagittal sinus
Dura mater
Gyrus (grey matter)
Falx cerebri
Grey matter
Lateral ventricle
Falx cerebri
(a)
(b)

Figs 4.3a and b: (a) Arachnoid granulation and (b) MRI of coronal section through superior sagittal sinus

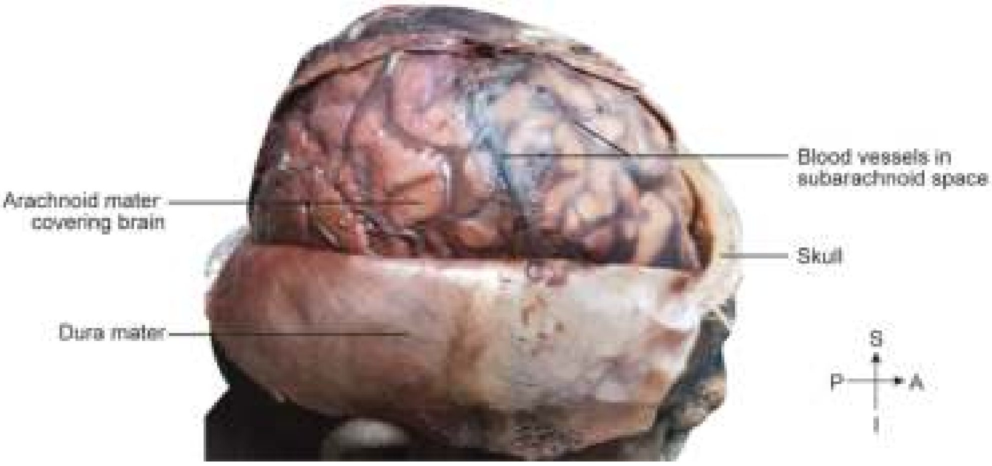

Arachnoid mater covering brain
Dura mater
Blood vessels in subarachnoid space
Skull
S
P
A
I

Fig. 4.4: Arachnoid mater

and 4.4). Thus, it bridges all irregularities of the brain. It enters the following sulcus/fissure:

1. Stem of lateral sulcus where it is pushed by lesser wing of sphenoid.
2. Longitudinal cerebral fissure where it is carried in by falx cerebri.

Note: The arachnoid mater cannot be identified in the hypophyseal fossa.

Relations

It is separated from the dura by the ***subdural space***, and from the pia by the ***subarachnoid space*** containing cerebrospinal fluid (CSF) and blood vessels.

Prolongations

1. It provides sheaths for the cranial nerves as far as their exit from the skull.
2. ***Arachnoid villi*** are small, finger-like processes of arachnoid tissue, projecting into the cranial venous sinuses. They absorb CSF.
3. With advancing age, the arachnoid villi enlarge in size to form pedunculated tufts, called ***arachnoid granulations***. These granulations may produce depressions in bone.

Note: Cerebrospinal fluid formed by choroid plexuses flows through the ventricles of the brain into the subarachnoid space to be absorbed via subarachnoid villi into the superior sagittal sinus.

PIA MATER

The pia (Latin *loving mother*) mater is a thin vascular membrane that closely invests the brain, dipping into various sulci and other irregularities of its surface. It comprises epi-pia and pia-glia (Fig. 4.5).

On the cerebellum, pia mater dips and forms folds in relation to larger fissures of cerebellum. It is pierced by blood vessels to nourish the brain and spinal cord.

Prolongations

1. ***Perivascular sheaths*****:** The pia mater provides sheaths around the vessels entering or leaving the brain substance.

   Note: ***Perivascular space*** (*Virchow-Robin's space*): The blood vessels in the substance of brain are surrounded by a sheath of external pia mater and inner arachnoid mater. The space between these two layers is called perivascular space.
2. ***Tela choroidea of ventricles*****:** These are folds of pia mater surrounded by ependymal lining.
3. ***Choroid plexus*****:** The tuft of capillaries and tela choroidea together forms choroid plexus. It produces CSF.
4. Sheaths around cranial nerves.

EXTRADURAL (EPIDURAL) AND SUBDURAL SPACES

The extradural or epidural space is a potential space between the inner aspect of skull bone and the endosteal layer of dura mater. Vertebral epidural space is present between vertebral column and spinal dura mater. The subdural space is also a potential space between the dura and arachnoid maters. These become actual spaces in pathological conditions.

The subdural space is traversed by cerebral veins on their path for draining into dural venous sinuses.

SUBARACHNOID SPACE

This is the space between the arachnoid and the pia maters. It is traversed by a network of arachnoid trabeculae which give it a ***sponge-like appearance*** (Fig. 4.5).

It surrounds the brain and spinal cord, and ends below at the lower border of the 2nd sacral vertebra.

The subarachnoid space contains CSF, and large vessels of the brain. Cranial nerves pass through the space.

Larger arteries lie in subarachnoid space. Smaller ones carry sheaths of pia. Subarachnoid space and perivascular spaces are separated by layer of pia mater.

Space between the nervous tissue and fold of pia mater with arterioles is known as ***Virchow-Robin perivascular space***.

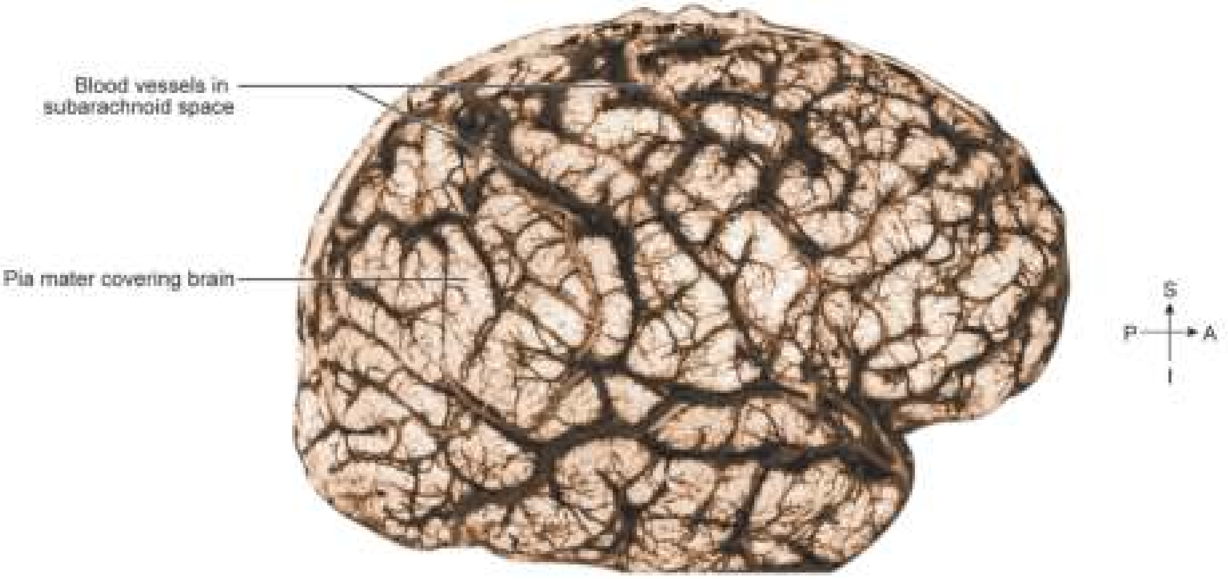


Fig. 4.5: Pia mater

Subarachnoid Cisterns

At the base of the brain and around the brainstem, the subarachnoid space forms intercommunicating pools, called *cisterns* (Latin *reservoir*). These reinforce the protective effect of CSF on the vital centres situated in the medulla. The subarachnoid cisterns are as follows (Flowchart 4.1 and Plate 4.2):

1. ***Cerebellomedullary cistern or cisterna magna:*** It is the largest cistern lying in the angle between medulla oblongata, cerebellum and occipital bone. It is triangular in section. It bridges the interval between inferior surface of cerebellum and medulla oblongata (Figs 4.6a and b). It receives CSF from the 4th ventricle via the median foramen of Magendie and the paired lateral foramina of Luschka.
   Contents:
   a. Vertebral artery and the origin of the posteroinferior cerebellar artery (PICA)
   b. Ninth (IX), tenth (X), eleventh (XI) and twelfth (XII) cranial nerves
   c. Choroid plexus.
2. ***Cisterna pontis:*** It is present on the ventral aspect of the pons. It is continuous with interpeduncular cistern cranially, with cerebellomedullary cistern behind and with spinal subarachnoid space caudally.
   Contents:
   a. Basilar artery and the origin of the anteroinferior cerebellar artery (AICA)
   b. Origin of the superior cerebellar arteries
   c. Sixth (VI) cranial nerve.
3. ***Interpeduncular cistern:*** This is a large cistern as the arachnoid mater passes across the two temporal lobes. The cistern is continuous with the subarachnoid spaces around anterior, middle and posterior cerebral arteries.
   Contents:
   a. Optic chiasma
   b. Bifurcation of the basilar artery
   c. Peduncular segments of the PCA
   d. Peduncular segments of the superior cerebellar arteries
   e. Perforating branches of the PCA
   f. Posterior communicating arteries (PCoA)
   g. Basal vein of Rosenthal
   h. Third (III) cranial nerve, which passes between the posterior cerebral and superior cerebellar arteries.
4. ***Cistern of lateral sulcus:*** It lies in front of each temporal pole and is formed due to bridging of arachnoid mater over the lateral sulcus. This cistern contains middle cerebral vessels.
5. ***Cistern of great cerebral vein (cisterna ambiens):*** This cistern lies in the space between splenium of corpus callosum and superior surface of cerebellum. It contains pineal gland and great cerebral vein of Galen.
6. ***Lumbar cistern:*** This is a large subarachnoid space in the lumbar region of the vertebral column distal to the termination of the spinal cord. In the space between L3 and L4 (which is part of the lumbar cistern), lumbar puncture is done to obtain a sample of CSF.

Note: The arterial pulsations within the cisterns help to force the CSF from the cisterns onto the superolateral surface of the hemispheres. The cisterns themselves form cushions around the medulla.

Communications

The subarachnoid space communicates with ventricular system of brain at:

1. A median foramen of Magendie
2. Two lateral foramina of Luschka, situated in the roof of the fourth ventricle. The CSF passes through these foramina from the fourth ventricle to subarachnoid space.

Prolongations

1. The space is prolonged into the arachnoid sheaths around nerves where it communicates with the neural lymphatics, particularly around the 1st, 2nd and 8th cranial nerves.
2. The space also extends into the pial sheaths around the vessels entering the brain substance (perivascular space). Thus, CSF comes into direct contact with nerve cells.

Flowchart 4.1: Subarachnoid space and cisterns

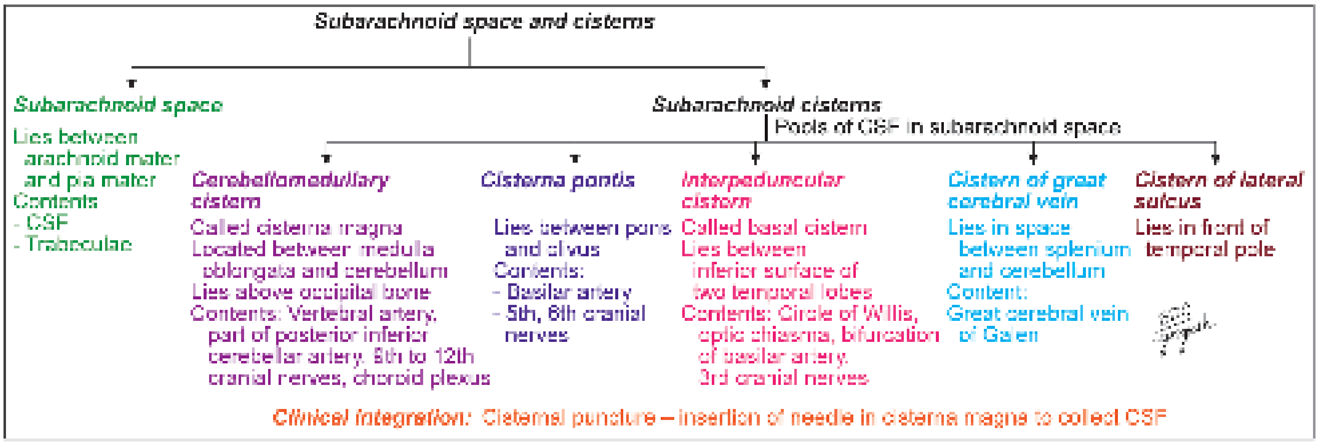
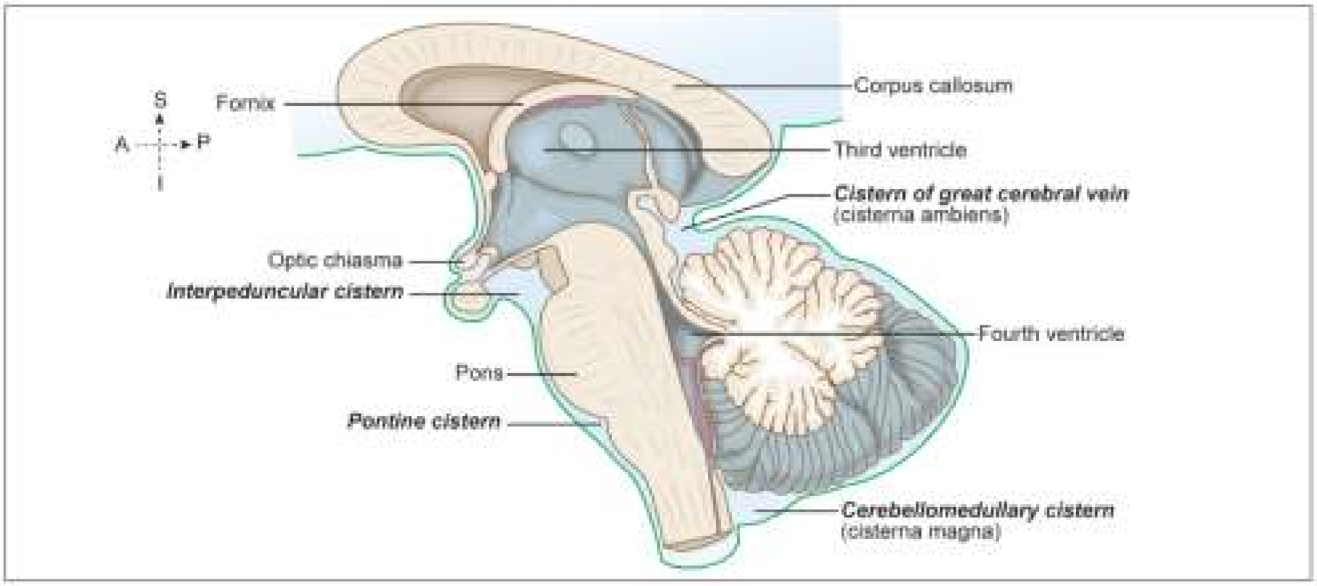
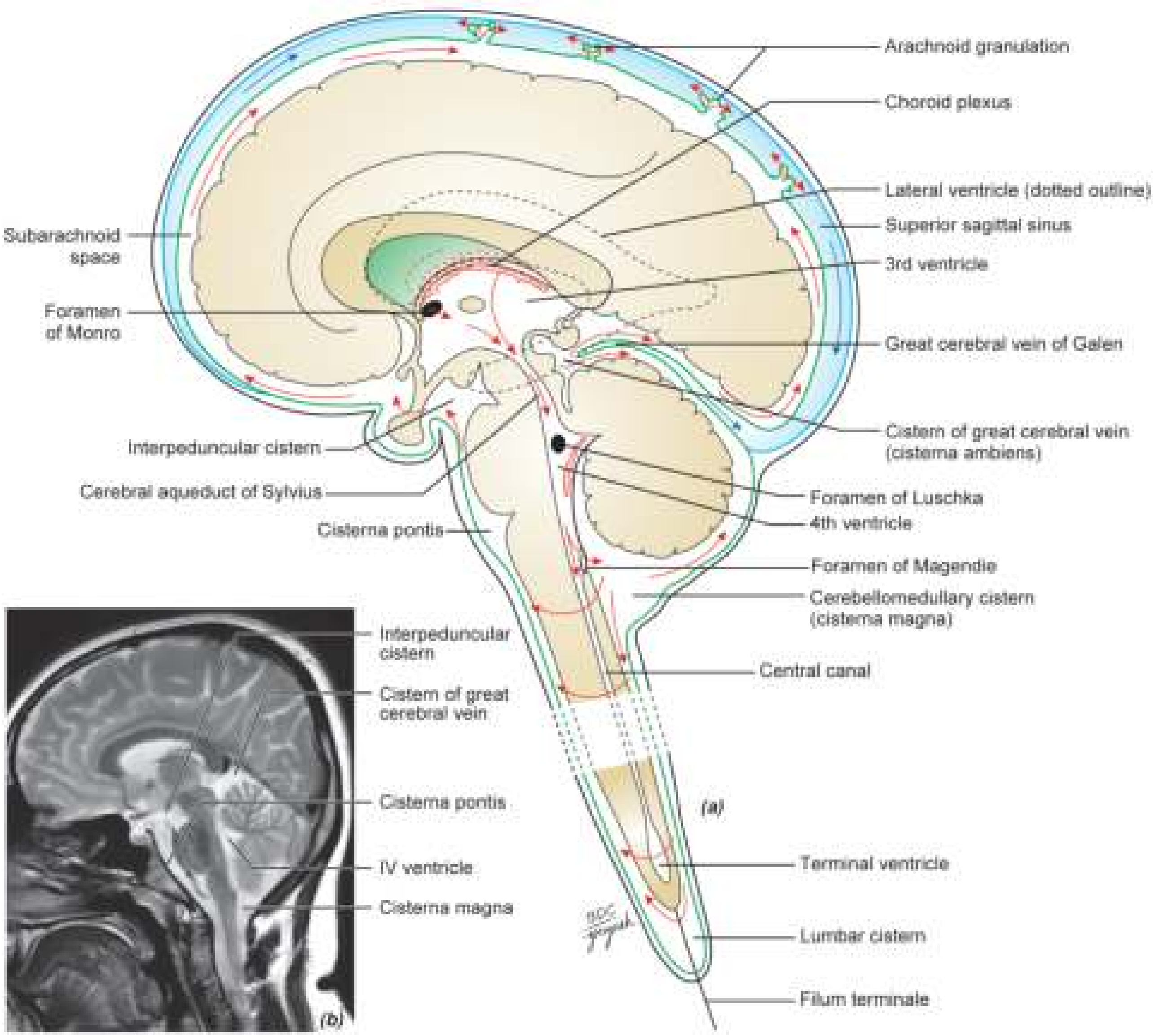

Subarachnoid space and cisterns
Subarachnoid space
Lies between arachnoid mater and pia mater
Contents
- CSF
- Trabeculae
Subarachnoid cisterns
Pools of CSF in subarachnoid space
Cerebellomedullary cistern
Called cisterna magna
Located between medulla oblongata and cerebellum
Lies above occipital bone
Contents: Vertebral artery, part of posterior inferior cerebellar artery, 9th to 12th cranial nerves, choroid plexus
Cisterna pontis
Lies between pons and clivus
Contents:
- Basilar artery
- 5th, 6th cranial nerves
Interpeduncular cistern
Called basal cistern
Lies between inferior surface of two temporal lobes
Contents: Circle of Willis, optic chiasma, bifurcation of basilar artery, 3rd cranial nerves
Cistern of great cerebral vein
Lies in space between splenium and cerebellum
Content:
Great cerebral vein of Galen
Cistern of lateral sulcus
Lies in front of temporal pole
Clinical integration: Cisternal puncture – insertion of needle in cisterna magna to collect CSF

Plate 4.2: Location of principal subarachnoid cisterns (midsagittal section, right medial view)


S
A
P
I
Fornix
Corpus callosum
Third ventricle
Cistern of great cerebral vein
(cisterna ambiens)
Optic chiasma
Interpeduncular cistern
Fourth ventricle
Pons
Pontine cistern
Cerebellomedullary cistern
(cisterna magna)


Arachnoid granulation
Choroid plexus
Lateral ventricle (dotted outline)
Superior sagittal sinus
3rd ventricle
Great cerebral vein of Galen
Cistern of great cerebral vein
(cisterna ambiens)
Foramen of Luschka
4th ventricle
Foramen of Magendie
Cerebellomedullary cistern
(cisterna magna)
Central canal
Terminal ventricle
Lumbar cistern
Filum terminale
Subarachnoid
space
Foramen
of Monro
Interpeduncular cistern
Cerebral aqueduct of Sylvius
Cisterna pontis
(a)
Interpeduncular
cistern
Cistern of great
cerebral vein
Cisterna pontis
IV ventricle
Cisterna magna
(b)

Figs 4.6a and b: CSF circulation: (a) Various cisterns of the brain including formation, circulation and absorption of cerebrospinal fluid. Arrows show the direction of flow of CSF and (b) MRI depicting the cisterns

CLINICAL NEUROANATOMY

- CSF can be obtained by:
  a. Lumbar puncture
  b. Cisternal puncture
  c. Ventricular puncture.

  Lumbar puncture is the easiest method and is commonly used.

  It is done by passing a needle in the interspace between the third and fourth lumbar spines.
- Biochemical analysis of CSF is of diagnostic value in various diseases.
- ***Papilloedema:*** The subarachnoid space sends extensions along the optic nerves till the back of eyeball. Increased CSF pressure compresses the wall of retinal vein leading to forward bulging of optic disc with oedema of the disc. Oedema of the optic disc is known as *papilloedema*. It can be viewed by an ophthalmoscope.
- ***Lumbar epidural space:*** The epidural space is the space between vertebral canal and dura mater. The procedure is same as lumbar puncture, the needle should reach only in the epidural space and not deep to it in the dura mater. Epidural space is utilized for giving anaesthesia or analgesia.
- Inflammation of pia mater and arachnoid mater is known as ***meningitis***. This is commonly tubercular or pyogenic. It is characterised by fever, marked headache, neck rigidity, and a changed biochemistry of CSF.

Competency:
AN56.2 Describe formation, circulation and absorption of CSF with its applied anatomy.

CEREBROSPINAL FLUID (CSF)

The cerebrospinal fluid is a modified tissue fluid. It is contained in the ventricular system of the brain and in the subarachnoid space around the brain and spinal cord. CSF replaces lymph in the CNS (Fig. 4.7, Flowchart 4.2).

Formation

1. Bulk of the CSF is formed by the *choroid plexuses* of the lateral ventricles and lesser amounts by the choroid plexuses of the 3rd and 4th ventricles (Fig. 4.7).
2. Possibly, it is also formed by the capillaries on the surface of the brain and spinal cord.

The total quantity of CSF is about 150 ml. It is formed at the rate of about 20 ml per hour or 500 ml per day.

The normal pressure of CSF is 60 to 100 mm H_2O.

Circulation

CSF passes from each lateral ventricle to the 3rd ventricle through the interventricular foramen of Monro. From the 3rd ventricle, it passes to the 4th ventricle through the cerebral aqueduct. From the 4th ventricle, the CSF passes to the subarachnoid spaces of the cerebrum and the vertebral canal through the median and lateral apertures of the 4th ventricle (Flowchart 4.3). Some of it passes down the central canal of spinal cord.

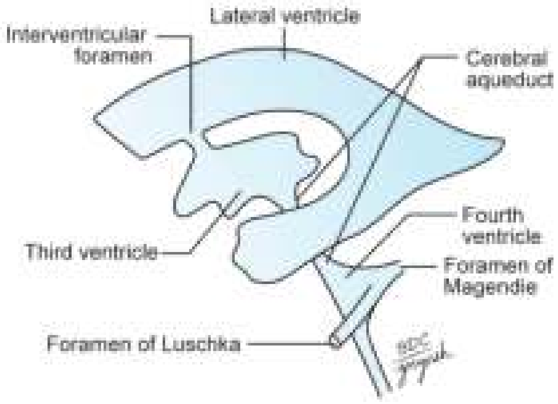
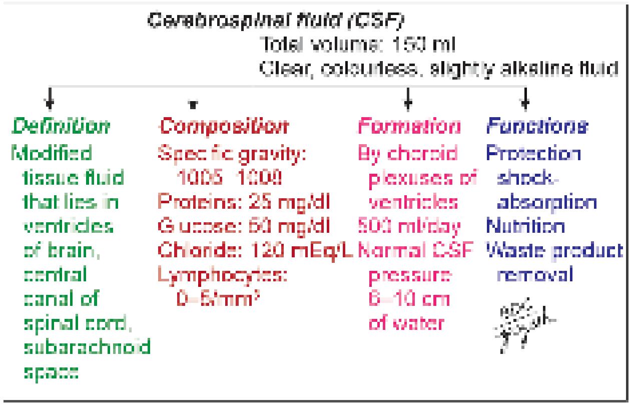
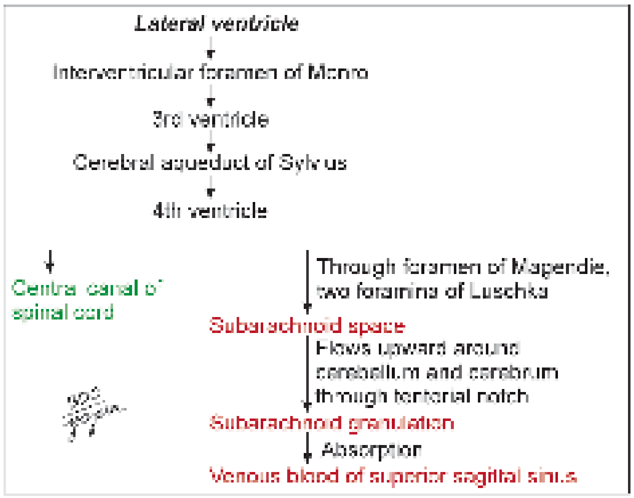

Lateral ventricle
Interventricular foramen
Cerebral aqueduct
Fourth ventricle
Third ventricle
Foramen of Magendie
Foramen of Luschka

Fig. 4.7: Ventricular system of brain

Flowchart 4.2: Cerebrospinal fluid


Cerebrospinal fluid (CSF)
Total volume: 150 ml
Clear, colourless, slightly alkaline fluid
Definition
Modified tissue fluid that lies in ventricles of brain, central canal of spinal cord, subarachnoid space
Composition
Specific gravity: 1005–1008
Proteins: 25 mg/dl
Glucose: 60 mg/dl
Chloride: 120 mEq/L
Lymphocytes: 0–5/mm³
Formation
By choroid plexuses of ventricles
500 ml/day
Normal CSF pressure 6–10 cm of water
Functions
Protection shock-absorption
Nutrition
Waste product removal

Flowchart 4.3: Circulation of cerebrospinal fluid (CSF)


Lateral ventricle
Interventricular foramen of Monro
3rd ventricle
Cerebral aqueduct of Sylvius
4th ventricle
Central canal of spinal cord
Through foramen of Magendie, two foramina of Luschka
Subarachnoid space
Flows upward around cerebellum and cerebrum through tentorial notch
Subarachnoid granulation
Absorption
Venous blood of superior sagittal sinus

Absorption

1. CSF is absorbed chiefly through the arachnoid villi and granulations, and is thus drained into the cranial venous sinuses.
2. It is also absorbed partly by the perineural lymphatics around the first, second and eighth cranial nerves.
3. It is also absorbed by veins related to spinal nerves.

Composition

CSF is a clear, colourless, slightly alkaline fluid.

Specific gravity: 1005–1008

Proteins: 25 mg/dl

Glucose: 50 mg/dl

Chloride: 120 mEq/L

Lymphocytes: 0–5/mm^3.

Functions of CSF

1. CSF decreases the sudden pressure or forces on delicate nervous tissue.
2. CSF ***nourishes*** nervous tissue. Only CSF comes in contact with neurons. Even blood cannot directly come in contact with neurons. It provides nourishment and returns products of metabolism to the venous sinuses.
3. Neurons cannot live without glucose and oxygen for more than 3–5 minutes. These are constantly provided by CSF.
4. Pineal gland secretions reach pituitary gland via CSF.
5. A major function of CSF is to ***cushion*** the brain within its solid vault. The brain and CSF have approximately the same specific gravity, so that the brain simply floats in the fluid.
6. There is no CSF–brain barrier, so drugs can reach the neurons through CSF.
7. There is blood–CSF barrier. There are no antibodies in CNS, making infections of brain very serious entity.

Competency:

AN63.2 Describe anatomical basis of congenital hydrocephalus.

CLINICAL NEUROANATOMY

- Drainage of CSF at regular intervals is of therapeutic value in ***meningitis***. Certain intractable headaches of unknown aetiology are also known to have been cured by a mere lumbar puncture with drainage of CSF.
- Obstruction in the vertebral canal produces ***Froin's syndrome*** or *loculation syndrome.* This is characterised by yellowish discolouration of CSF (xanthochromia) below the level of obstruction, and its spontaneous coagulation after withdrawal due to a high protein content. Biochemical examination of such fluid reveals that the protein content is raised, but the cell content is normal. This is known as *albuminocytologic dissociation*.
- ***Hydrocephalus***: It is the dilatation of the ventricular system and occurs due to obstruction of CSF circulation. It may be of the following types (Figs 4.8 and 4.9):
  a. ***Communicating hydrocephalus:*** If the obstruction is outside the ventricular system, usually in the subarachnoid space or arachnoid granulations, it is termed *communicating hydrocephalus*. This occurs due to fibrosis following meningitis.

     It is also called external hydrocephalus.

     Clinical features are:
     - Head size is rather large.
     - Tense anterior fontanelle
     - Dilated veins over thin scalp.

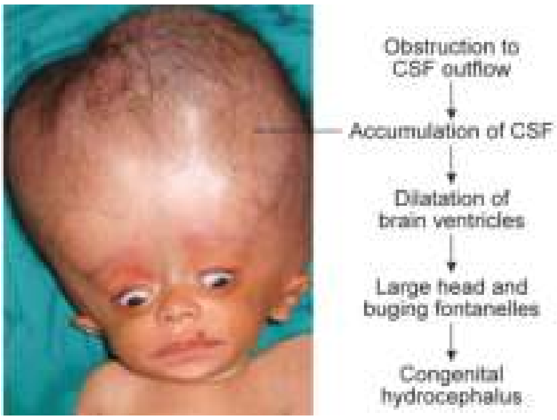
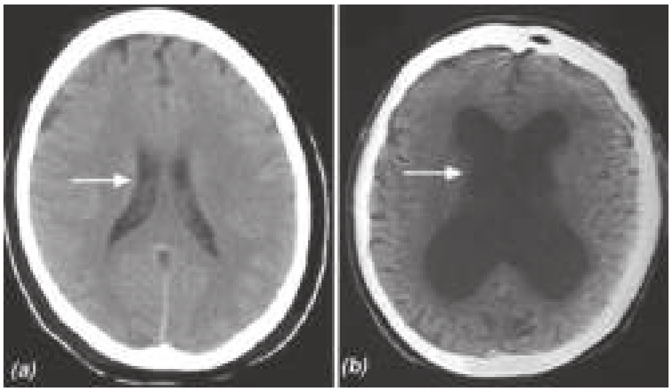

Obstruction to CSF outflow
Accumulation of CSF
Dilatation of brain ventricles
Large head and buging fontanelles
Congenital hydrocephalus

Fig. 4.8: Hydrocephalic child



Figs 4.9a and b: (a) Normal ventricles and (b) dilated ventricles in hydrocephalic child (Ventricles are dark in colour and marked by arrow)

  b. ***Non-communicating hydrocephalus:*** If the obstruction is within the ventricular system, it is called *non-communicating* or *internal hydrocephalus*. This is usually caused by a tumour or inflammation. A shunt procedure is employed to divert the CSF from the ventricular system into the peritoneal cavity.

Facts to Remember

- Leptomeninges = arachnoid mater + pia mater
- Dura mater is toughest and pia mater is most delicate among the meninges.
- CSF is present in the subarachnoid space, ventricles of brain, and central canal of spinal cord.
- CSF is produced by choroid plexuses and absorbed by subarachnoid granulations.
- Increased formation or decreased absorption or any obstruction in its flow leads to hydrocephalus.

BDC's Anatomy e-book

1. Anatomical basis of hydrocephalus
2. Further reading
3. Viva voce questions

Chapter

5

Spinal Cord

The spinal cord is the long cylindrical lower part of central nervous system. It is the main pathway for information connecting the brain and peripheral nervous system.

It occupies upper two-thirds of vertebral canal and is enclosed in the three meninges. It gives rise to 31 pairs of spinal nerves and retains the basic structural pattern.

Competency:
AN57.2 Describe extent of spinal cord in child and adult with its clinical implication.

Features

It is cylindrical and slightly flattened anteroposteriorly.

Measurements

Length:	18 inches or 45 cm in an adult male 42 cm in adult female.
Weight:	30 g.

It is surrounded by the three meninges (Fig. 5.1).

Extent

It extends from upper border of atlas vertebra to the lower border of first lumbar vertebra in an adult. In newborn, it extends up to L3 vertebra. Superiorly, it is continuous with the medulla oblongata; inferiorly, it terminates as conus medullaris. The spinal cord extends in the lower part of 1st lumbar vertebra as *conus medullaris*.

SPINAL MENINGES

The spinal cord is surrounded by three meninges (Fig. 5.2):

1. *Dura mater*: It is the outermost covering and extends from the foramen magnum to the lower border of second sacral vertebra.
2. *Arachnoid mater* (cobweb-like in Latin) is the middle layer and a thin transparent membrane that loosely surrounds the spinal cord. It also extends up to the lower border of S2 vertebra.
3. *Pia mater* (loving mother in Latin): It is the innermost layer and a thin vascular membrane that closely invests the spinal cord.

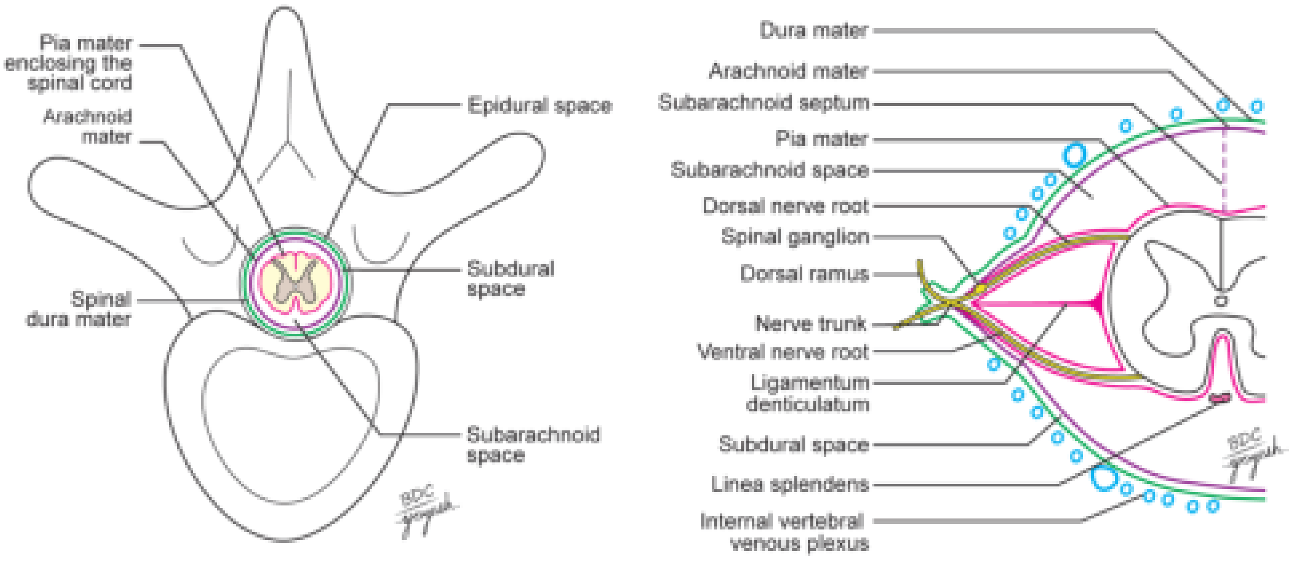

Pia mater enclosing the spinal cord
Arachnoid mater
Spinal dura mater
Epidural space
Subdural space
Subarachnoid space
Dura mater
Arachnoid mater
Subarachnoid septum
Pia mater
Subarachnoid space
Dorsal nerve root
Spinal ganglion
Dorsal ramus
Nerve trunk
Ventral nerve root
Ligamentum denticulatum
Subdural space
Linea splendens
Internal vertebral venous plexus

Fig. 5.1: Spinal cord with its meninges

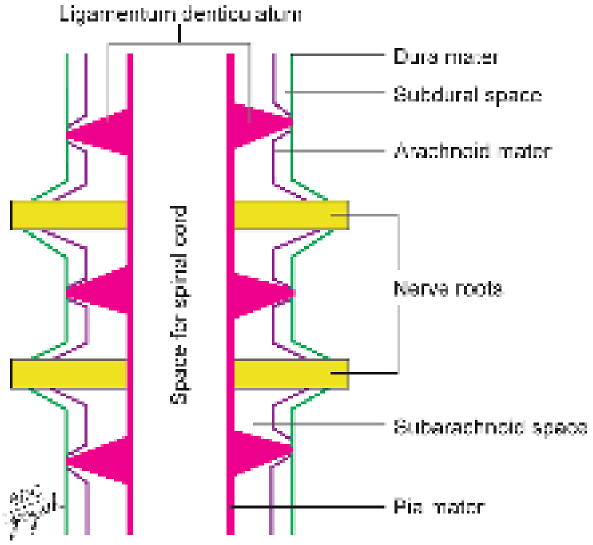


Fig. 5.2: Ligamentum denticulatum and its relationship to the dura mater and to the arachnoid mater

Modifications of Pia Mater

The spinal pia mater undergoes **modification** as follows to keep the spinal cord in position during the movements of the vertebral column.

1. ***Ligamenta denticulata:*** They are 21 pairs of teeth-like projections. They fuse laterally with the arachnoid and dura maters midway between the exits of the roots of adjacent spinal nerves. The highest process attaches immediately superior to foramen magnum. The ligamentum denticulatum keeps the spinal cord in position.
2. ***Filum terminale:*** Below the level of conus medullaris, only pia mater is continued as a thin fibrous cord, the ***filum terminale***. It is 20 cm long and after leaving through sacral hiatus ends by getting attached to the periosteum of dorsal surface of first segment of coccyx. It consists of two parts:
   a. *Filum terminale internum*, the upper part which is 15 cm long which extends up to lower border of second sacral vertebra.
   b. *Filum terminale externum*, the lower part which is outside the dura mater and is attached to the first segment of the coccyx.

   Note: Between the lower border of L1 and S2 vertebrae, the subarachnoid space contains spinal nerve roots which constitute the cauda equina. It is due to this feature that lumbar puncture is done below L2 vertebra without any danger to spinal cord.
3. ***Subarachnoid septum*:** It is the midline septum of pia mater which connects the posterior surface of spinal cord with arachnoid mater.
4. ***Linea splendens:*** It is a thickening seen at the anteromedian sulcus in the lower part of the spinal cord.

Spaces Surrounding the Spinal Cord

1. ***Epidural space:*** The spinal cord is enclosed only by the meningeal layer of dura mater. The space between the meningeal layer and endosteum of the vertebral canal is called *epidural space*, where epidural anaesthesia can be given. The epidural space is filled with adipose tissue, and it contains a network of blood vessels.
2. ***Subdural space*:** The space between dura mater and arachnoid mater is called *subdural space*. The arachnoid and pia maters are separated by subarachnoid space which contains cerebrospinal fluid.
3. ***Subarachnoid space*:** It is the space between arachnoid mater and pia mater. It is filled with cerebrospinal fluid (CSF).

   Note: The dura and arachnoid along with subarachnoid space containing CSF extend up to 2nd sacral vertebra.
4. ***Lumbar cistern*:** In the lower part of the vertebral column below the lower end of spinal cord, the subarachnoid space forms a pool of CSF. It is called lumbar cistern.

CLINICAL NEUROANATOMY

- ***Epidural anaesthesia*:** In this, anaesthetic agent is injected in the epidural space to block the pain in a particular region of the body, that is, to anesthetise a particular part. It is useful for lower extremity, gynaecological surgeries, caesarean section, and so on (Fig. 5.3).
- In ***lumbar puncture*** or spinal tap a needle is introduced to withdraw cerebrospinal fluid from the subarachnoid space, usually from the lumbar region of the spine (Fig. 5.4).

  The lumbar puncture in a child is done at a lower level—L4 vertebra as spinal cord extends till L3 vertebra at birth. As it ascends till level of L1 vertebra in adult, lumbar puncture is done at level of L3 vertebra to prevent injury to spinal cord.

  Indications: Lumbar puncture is performed to collect CSF for diagnostic purpose in meningitis, subarachnoid haemorrhage, and other neurological disorders or for therapeutic purpose to reduce raised intracranial pressure.

  Contraindications: It should be avoided in the following conditions:
  – Infection at the site of lumbar puncture
  – Cases with signs of increased intracranial pressure
  – Severe thrombocytopenia or other bleeding disorders.

  Position of a patient: Patient lying down on one side (or sitting) with fully flexed spine. It will raise the lower level of spinal cord.
- ***Ligamentum denticulatum – surgical guide*:** In cordotomy surgery: A part of spinal cord behind the ligamentum denticulatum is sectioned to relive pain. A part of spinal cord anterior to ligamentum denticulatum is sectioned to paralyze muscles. The 1st lumbar nerve lies just below the last pair of ligamentum denticulatum. It helps for identification of desired spinal nerves.

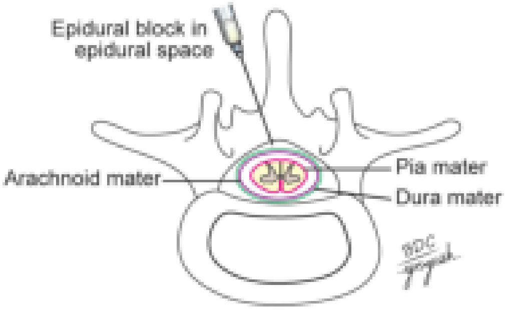

Epidural block in epidural space
Arachnoid mater
Pia mater
Dura mater

Fig. 5.3: Lumbar epidural anaesthesia

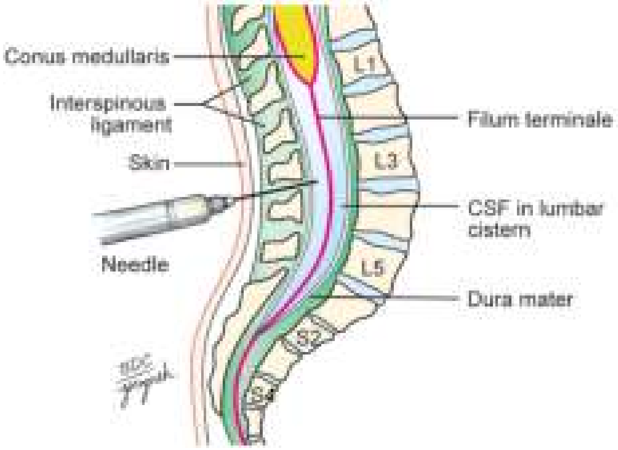

Conus medullaris
Interspinous ligament
Skin
Needle
L1
L3
L5
S2
S4
Filum terminale
CSF in lumbar cistern
Dura mater

Fig. 5.4: Lumbar puncture in an adult

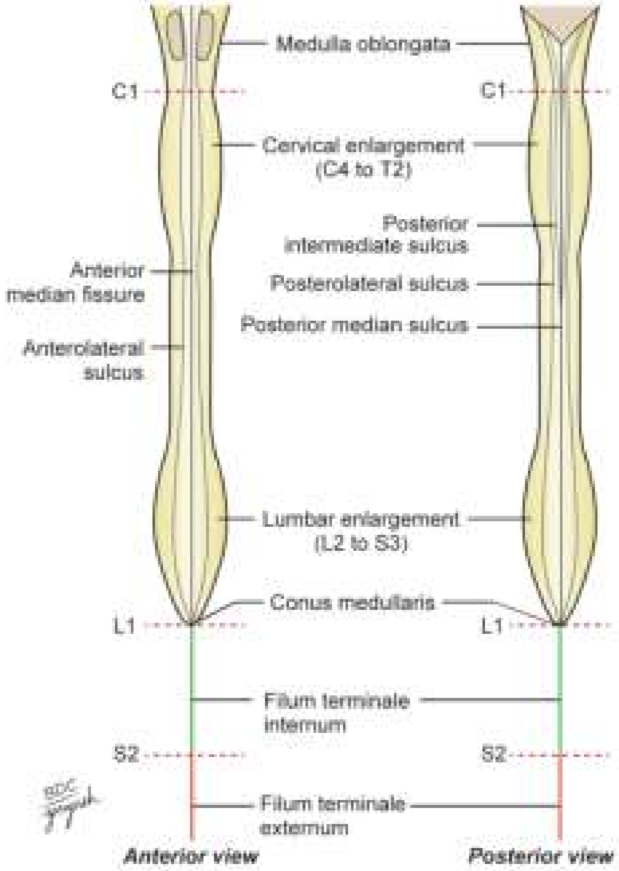

Medulla oblongata
C1
C1
Cervical enlargement (C4 to T2)
Posterior intermediate sulcus
Anterior median fissure
Posterolateral sulcus
Posterior median sulcus
Anterolateral sulcus
Lumbar enlargement (L2 to S3)
Conus medullaris
L1
L1
Filum terminale internum
S2
S2
Filum terminale externum
Anterior view
Posterior view

Fig. 5.5: Extent and external features of the spinal cord

Competency:
AN57.1 Identify external features of spinal cord.

EXTERNAL FEATURES OF SPINAL CORD

The external features of spinal cord include (Fig. 5.5):

1. Fissures and sulci
2. Attachments of spinal nerves
3. Enlargements
4. Cauda equina.

Fissures and Sulci

The spinal cord is flat anteroposteriorly. The spinal cord shows the following sulci and fissures:

1. *Anterior median fissure* is a deep groove in the midline anteriorly. It is lined by pia mater. It contains anterior spinal artery.
2. *Posterior median sulcus* is a shallow midline sulcus posteriorly. From it, a septum of neurological tissue (*posterior median septum*) extends into the substance of the spinal cord to a variable extent.
3. *Ventrolateral* (*anterolateral*) *sulcus* is indistinct. The ventral rootlets of the spinal nerve emerge at this sulcus.
4. *Dorsolateral* (*posterolateral*) *sulcus* lies on each side, at about 2 mm from the posterior median sulcus. It corresponds to the attachment of dorsal roots of spinal nerve.
5. *Dorsointermediate* (*posterointermediate*) *sulcus* lies between the posterior median and posterolateral sulcus. It is present only in cervical and upper thoracic levels.

Attachment of Spinal Nerve and Spinal Segments

The 31 pairs of spinal nerves are attached to the spinal cord. These include 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal pairs of nerves (Plate 5.1).

Each spinal nerve is attached to the spinal cord by 2 roots: Ventral and dorsal nerve roots.

- *Ventral* or *anterior motor root* carries motor or efferent fibres from the spinal cord.
- *Dorsal* or *posterior sensory root* carries sensory or afferent fibres. It shows an oval swelling called *dorsal root ganglion*. This ganglion contains pseudounipolar neurons. Their fibres divide in T-shaped manner and give rise to:
  a. Central processes that enter the spinal cord
  b. Peripheral processes that join the ventral root to form a spinal nerve.

Note: As the spinal cord is much shorter than the length of the vertebral column, the spinal segments do not lie opposite the corresponding vertebrae. In estimating the position of a spinal segment in relation to the surface of the body, it is important to remember that a vertebral spine is always lower than the corresponding spinal segment (Table 5.1).

Note: During the third month of embryonic development, the spinal cord extends the entire length of the vertebral canal and both grow

Plate 5.1: Spinal cord with attachment of nerve roots on right side

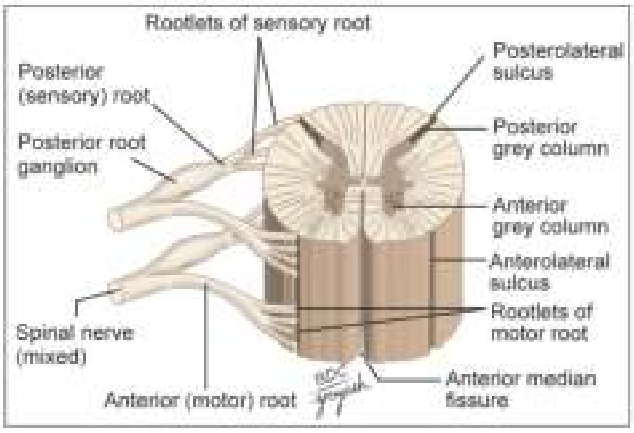

Rootlets of sensory root
Posterior (sensory) root
Posterolateral sulcus
Posterior root ganglion
Posterior grey column
Anterior grey column
Anterolateral sulcus
Rootlets of motor root
Spinal nerve (mixed)
Anterior (motor) root
Anterior median fissure

TABLE 5.1: Vertebral level of spinal cord segments

Spinal segment	*Vertebral level*
C1, C2	Same level
C3 to C6	One vertebra above
C7, C8, T1 to T5	Two vertebrae above
T6 to T10	Three vertebrae above
T11, T12	Three to five vertebrae above
L1, L2	At T10 vertebra
L3, L4	At T11 vertebra
L5	At T12 vertebra
Sacral and coccygeal segments	At L1 vertebra

Note: These are approximate levels.

at about the same rate. As development continues, the body and the vertebral column continue to grow at a much greater rate than the spinal cord proper. The outcome of this uneven growth is that the adult spinal cord extends to the level of the first or second lumbar vertebrae, and the nerves grow to exit through the same intervertebral foramina as they did during embryonic development. This growth of the nerve roots occurring within the vertebral canal, results in the lumbar, sacral, and coccygeal roots extending to their appropriate vertebral levels.

Spinal Nerves

Each spinal nerve arises by a series of six to eight dorsal and ventral nerve rootlets. These rootlets unite in or near the intervertebral foramen to form the spinal nerve (Fig. 5.6).

Dorsal root ganglion: As the dorsal rootlets converge, there is a swelling, the dorsal or posterior root ganglion, which houses the cell bodies of all the sensory neurons in that particular nerve. The neurons are pseudounipolar type.

Branches

1. *Dorsal ramus:* It supplies the dorsal one-third of the body wall. Dorsal rami do not supply the limbs.
2. *Ventral ramus:* It supplies the ventral two-thirds of the body wall *including the limbs*.

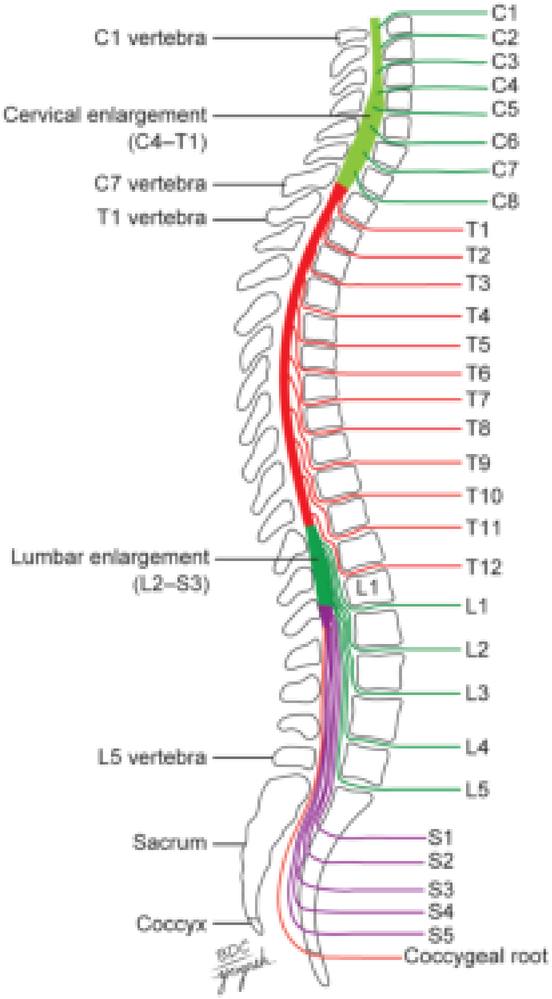

C1 vertebra
Cervical enlargement (C4–T1)
C7 vertebra
T1 vertebra
Lumbar enlargement (L2–S3)
L5 vertebra
Sacrum
Coccyx
L1
C1
C2
C3
C4
C5
C6
C7
C8
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
Coccygeal root

Fig. 5.6: The spinal cord with 31 pairs of spinal nerves

Enlargements

Limbs form the appendages of the trunk. Their muscles have to be supplied by neurons of spinal cord. Neurons at appropriate levels form enlargements to be able to supply increased musculature. It presents:

a. ***Cervical enlargement*** for supply of upper limb muscles. This extends from C3 to T2 spinal segments with maximum diameter of 38 mm at level of C6 segment (Fig. 5.6, Table 5.2) (*Reference*: Gray's Anatomy, 42nd Edn.).

b. ***Lumbar enlargement*** for supply of muscles of lower limb. It extends from the level of L1 to S3 segments (*Reference*: Gray's Anatomy, 42nd Edn.). Its maximum diameter is 35 mm at the level of S1 segment.

TABLE 5.2: Enlargement of spinal cord

Feature	*Cervical enlargement*	*Lumbar enlargement*
Extent	From C3–T2 spinal segments	From L1 to S3 spinal segments
Maximum diameter and its location	3.8 cm at C6 spinal segment	3.5 cm at T12 vertebral level
Function	Innervation of upper limb	Innervation of lower limb

Cauda Equina

Dorsal and ventral nerve roots of right and left sides of L2 to L5, S1 to S5 and Co1 nerves lie almost vertically around filum terminale. These are called cauda equina as these resemble a horse's tail.

The dorsal and ventral nerve roots of one segment join together at respective intervertebral foramen to exit as the spinal nerve (Fig. 5.7).

Note: There are 40 nerve roots at the beginning of cauda equina. These are dorsal and ventral nerve roots of right and left sides for each segment. So each segment has 4 nerve roots. Thus, there are 4 × 4 = 16 lumbar nerve roots; 4 × 5 = 20 sacral nerve roots; and 4 × 1 = 4 coccygeal nerve roots, making it to 40 nerve roots. One dorsal root and one ventral root joins to form one spinal nerve and leaves through the foramen on one side. So at every intervertebral foramen, 4 nerve roots exit the cauda equina; leaving it thinner. At the end, only filum terminale remains to be attached to the coccyx.

CLINICAL NEUROANATOMY

Conus medullaris syndrome: Due to injury to S2–S4 segments of spinal cord. Features are:

a. Anaesthesia in the perineum. The region is supplied by these three segments.
b. Involvement of bladder and bowel is early as S2–S4 segments carry sacral component of the parasympathetic system which supplies the bladder and lower bowel.
c. Sexual functions are affected as same nerves carry out sexual functions as well.

Cauda equina syndrome: Damage to cauda equina results in:

1. Lower motor neuron paralysis of lower limbs
2. Loss of tendon reflexes of lower limb
3. Severe root pain
4. Saddle-shaped anaesthesia
5. Sexual dysfunction
6. Late involvement of urinary bladder.

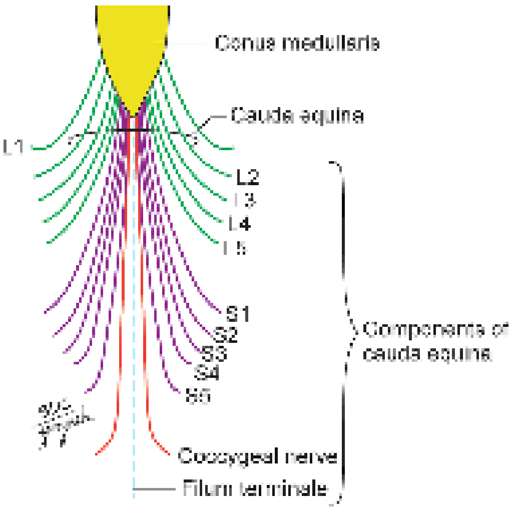

Conus medullaris
Cauda equina
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
Components of cauda equina
Coccygeal nerve
Filum terminale

Fig. 5.7: Cauda equina

DISSECTION

Study the spinal cord after it was removed from vertebral canal (*see* Chapter 11, *BD Chaurasia's Human Anatomy*, *Volume 3*) and separated from the dura mater and arachnoid mater. Identify the dorsal root by the presence of dorsal root ganglion or spinal ganglion. Note the position of cervical enlargement in the upper part and lumbosacral enlargement in the lower part. See the numerous nerve roots surrounding the filum terminale forming the cauda equina.

Cut transverse sections of spinal cord at cervical, thoracic, lumbar, and sacral regions to note the shape and size of the horns in relation to white matter.

INTERNAL STRUCTURE OF SPINAL CORD

Spinal cord consists of (Fig. 5.8):

1. Central grey matter
2. Peripheral white matter
3. Central canal containing CSF. The canal is lined by single layer of ependymal cells.

GREY MATTER OF SPINAL CORD

The grey matter is in the form of 'H' with a grey commissure joining the grey matter of right and left sides.

Grey matter comprises one ***posterior horn*** and one ***anterior horn*** on each side in the entire extent of the cord. Only in T1–L2 and S2–S4 segments, there is an additional ***lateral horn*** for the supply of the viscera. This horn is a part of the autonomic nervous system.

The dorsal horn is found at all spinal cord levels and is comprised of sensory neurons that receive and process incoming somatosensory information. From there, ascending projections emerge to transmit the sensory information to the diencephalon.

The ventral horn comprises *motor neurons* that innervate skeletal muscle. Nerve cells in the grey substance are multipolar, varying much in their morphology.

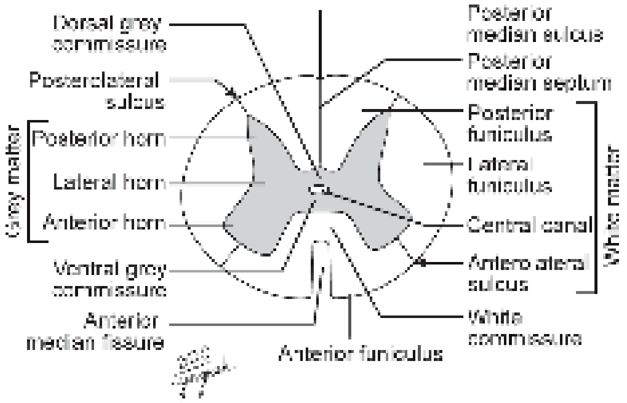

Dorsal grey commissure
Posterolateral sulcus
Grey matter
Posterior horn
Lateral horn
Anterior horn
Ventral grey commissure
Anterior median fissure
Anterior funiculus
Posterior median sulcus
Posterior median septum
Posterior funiculus
Lateral funiculus
Central canal
Anterolateral sulcus
White commissure
White matter

Fig. 5.8: Transverse section of the spinal cord

Structure of Grey Matter

The neurons of grey matter of spinal cord are multipolar and can be grouped functionally as motor neurons, interneurons, and sensory neurons.

Motor Neurons

These are present in anterior and lateral horns. These are of two types: Alpha and gamma neurons.

a. *Alpha neurons*: These are large cells (25 µm or more in diameter). They supply the extrafusal fibres of skeletal muscle.

b. *Gamma neurons*: These are small multipolar neurons (15–25 µm in diameter). They supply the intrafusal fibres of muscle spinal.

Sensory neurons are present in posterior horn. These are small neurons. They receive inputs from the neurons of dorsal root ganglion. Their axons form ascending or intersegmental tracts.

Interneurons (internuncial neurons) are small associated neurons. They connect different type of neurons.

Note: Many of the neurons of the spinal grey matter are Golgi type I and Golgi type II nerve cells. The axons of ***Golgi type I*** are long and pass out of the grey matter into the ventral spinal roots or the fibre tracts of the white matter. The axons and dendrites of the ***Golgi type II*** cells are largely confined to the neighbouring neurons in the grey matter. ***Renshaw cells*** are Golgi type II neurons and located in the anterior horn.

Shape and size of the horns differ in different segments due to functional reasons (Fig. 5.9) and shown in Table 5.3.

CLINICAL NEUROANATOMY

- ***Poliomyelitis:*** It is a viral disease which involves anterior horn cells leading to flaccid paralysis of the affected segments. It is a lower motor neuron paralysis (Figs 5.10 and 5.11). Virus passes from the digestive system to neurons via axonal transport. If poliomyelitis affects the upper cervical segments of spinal cord, it may be fatal because of the involvement of C4 segment which supplies the diaphragm through phrenic nerve.
- ***Tabes dorsalis*** (Fig. 5.11): It occurs during tertiary stage of syphilis. There is degenerative lesions of dorsal nerve roots and of posterior white columns. Its feature is severe pain in lower limbs, as the disease occurs in lower thoracic and lumbosacral segments. The lower limbs are mainly affected.

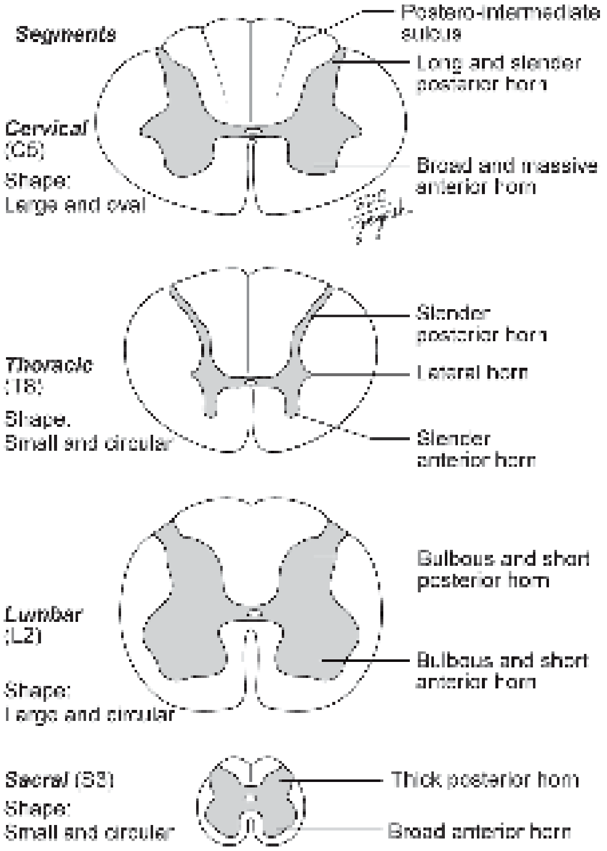

Segments
Postero-intermediate sulcus
Long and slender posterior horn
Cervical (C5)
Shape: Large and oval
Broad and massive anterior horn
Slender posterior horn
Thoracic (T8)
Lateral horn
Shape: Small and circular
Slender anterior horn
Bulbous and short posterior horn
Lumbar (L2)
Bulbous and short anterior horn
Shape: Large and circular
Sacral (S3)
Shape: Small and circular
Thick posterior horn
Broad anterior horn

Fig. 5.9: Features of spinal cord at various levels

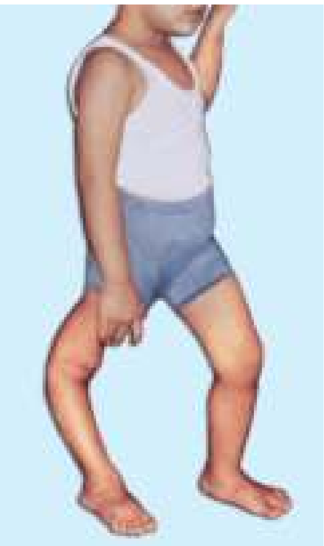


Fig. 5.10: Poliomyelitis of right lower limb

TABLE 5.3: Shape of horns in different segments of spinal cord

Segments of spinal cord	*Posterior horn*	*Lateral horn*	*Anterior horn*
Cervical, oval shape (Fig. 3.4)	Slender	Absent	Narrow in 1–3 segments Broad in C4 to C8 segments for supply of upper limbs
Thoracic, circular shape	Slender	Present for thoracolumbar outflow	Slender in T2–T12 segments, broad in T1 segment
Lumbar, circular shape	Bulbous	Present only in lumbar 1 and 2 segments	Bulbous for supply of lower limbs
Sacral, circular but smaller	Thick	Group of cells in sacral 2–4 segments for sacral outflow	Bulbous for supply of lower limbs

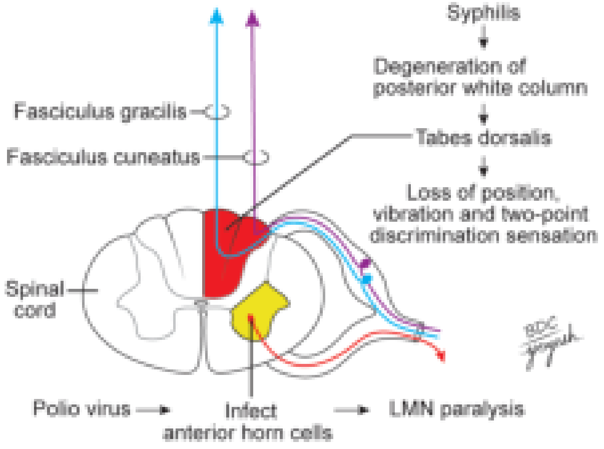

Syphilis
Degeneration of posterior white column
Tabes dorsalis
Loss of position, vibration and two-point discrimination sensation
Fasciculus gracilis
Fasciculus cuneatus
Spinal cord
Polio virus
Infect anterior horn cells
LMN paralysis

Fig. 5.11: Tabes dorsalis and poliomyelitis

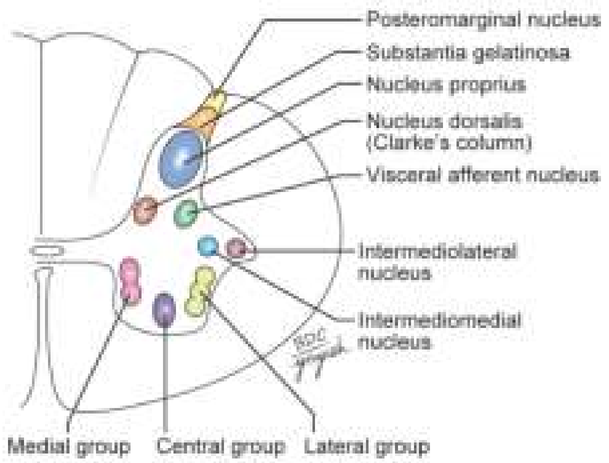

Posteromarginal nucleus
Substantia gelatinosa
Nucleus proprius
Nucleus dorsalis (Clarke's column)
Visceral afferent nucleus
Intermediolateral nucleus
Intermediomedial nucleus
Medial group
Central group
Lateral group

Fig. 5.12: Cell groups in spinal cord

Nerve Cell Groups (Nuclei) of Grey Columns

The grey matter of spinal cord is arranged in three horns. Anterior is motor, lateral being visceral efferent and afferent in function, and posterior is sensory in function.

Nuclei in Anterior Grey Column or Horn

The anterior horn is divided into a ventral part, head and a dorsal part, base. The nuclei in anterior horn innervate the skeletal muscles. Most prominent neurons are alpha neurons. Their axons leave the spinal cord through ventral nerve roots to innervate skeletal muscles. Smaller neurons are gamma neurons. These supply intrafusal fibres of muscle spindles. The cells in the anterior horn are arranged in the three main groups: medial, lateral and central (Fig. 5.12).

1. ***Medial group:*** It is present throughout the extent of spinal cord and innervates the axial muscles of the body. It is further divided into anteromedial and posteromedial groups:
2. ***Lateral group:*** Present only in the cervical and lumbar enlargements and supplies musculature of limbs. It is subdivided into three subgroups.
   a. *Anterolateral* supplying proximal muscles of limbs (shoulder and arm/gluteal region and thigh).
   b. *Posterolateral* supplying intermediate muscles of limbs (forearm/leg).
   c. *Post-posterolateral* innervating the distal segment (hand/foot).
3. ***Central group:*** Only in upper cervical segments as phrenic nerve nucleus and nucleus of spinal root of accessory nerve.

Nuclei in Lateral Grey Column or Horn

Nuclei in lateral horn are as follows (Fig. 5.12):

1. ***Intermediolateral nucleus:*** This acts as both efferent and afferent nuclear columns. This nucleus is seen at two levels.
   a. From T1 to L2 segments—giving rise to preganglionic sympathetic fibres (thoracolumbar outflow).
   b. From S2 to S4 segments—giving rise to preganglionic parasympathetic fibres chiefly for the pelvic viscera.

   At these two levels, the intermediolateral cell column receives visceral afferent fibres.
2. ***Intermediomedial nucleus:*** This is mostly internuncial neuronal column.

Nuclei in Posterior Grey Column or Horn

The four main afferent nuclei are seen in this are (Fig. 5.12):

1. ***Posteromarginal nucleus:*** Thin layer of neurons caps the posterior horn. It receives some of incoming dorsal root fibres.
2. ***Substantia gelatinosa:*** This is found at the tip of posterior horn through the entire extent of spinal cord. Here first order neurons of lateral spinothalamic tract synapse.
3. ***Nucleus proprius:*** It lies subjacent to the substantia gelatinosa throughout the entire extent of cord. 1–3 groups of nuclei are present in laminae I–IV. It is concerned with sensory associative mechanism. The axons originating project to the thalamus via the anterior spinothalamic tract and to the cerebellum via ventral spinocerebellar tract.
4. ***Nucleus dorsalis of Clarke*** also known as thoracic nucleus at the medial part of base of posterior horn extending from C8 to L3 segments. These are situated in laminae V and VI. It contains interneurons.

Laminar Organisation in Spinal Cord

In thick sections, spinal cord neurons appear to have a laminar (layered) arrangement. Ten layers of neurons are recognised, also known as ***laminae of Rexed*** (Table 5.4). These are numbered consecutively by Roman numerals, starting at the tip of the dorsal horn and moving ventrally into ventral horn (Fig. 5.13).

Laminae I to IV, in general, are concerned with exteroceptive sensation and comprise the dorsal horn, whereas laminae V and VI are concerned primarily with proprioceptive sensations. Lamina VII is equivalent to the intermediate zone and acts as a relay between muscle spindle to midbrain and cerebellum, and laminae VIII–IX comprise the ventral horn and contain mainly motor neurons. The axons of these neurons innervate mainly skeletal muscle. Lamina X surrounds the central canal and contains neuroglia.

TABLE 5.4: Rexed laminae

Lamina	*Corresponding grey column*
I	Posteromarginal nucleus
II	Substantia gelatinosa
III	Nucleus proprius
IV	Nucleus proprius
V	Base of dorsal horn
VI	
VII	Nucleus dorsalis Lateral horn (intermediolateral, intermediomedial nuclei)
VIII	Anterior horn of thoracic region Medial group of anterior horn in cervical and lumbosacral region
IX	Lateral group of nuclei of anterior horn
X	Surrounds the central canal

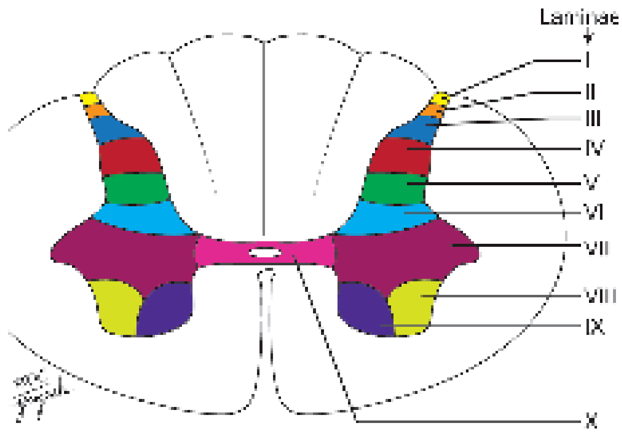

Laminae
I
II
III
IV
V
VI
VII
VIII
IX
X

Fig. 5.13: Various laminae in spinal cord

WHITE MATTER OF SPINAL CORD

The white matter of the spinal cord surrounds the grey matter. It appears white due to presence of myelinated nerve fibres.

Divisions of White Matter

The white matter of spinal cord is divided into right and left halves by *anterior median fissure* and *posterior median septum*. Each of the spinal cord shows three column or fasiculi of white matter:

1. *Anterior* (*ventral*) *white column* (*funiculus*) lies between anterior median fissure and the lateralmost fibres of ventral root of spinal nerve.
2. *Lateral white column* (*funiculus*) lies between the lateralmost fibres of ventral root and posterolateral sulcus.
3. *Posterior or dorsal column* (*funiculus*) lies between posterior median sulcus and posterolateral sulcus.

Types of Fibres in White Matter

The white matter of spinal contains three types of fibres:

1. *Sensory fibres* include central processes of pseudounipolar neurons of dorsal root ganglion and axons of dorsal horn cells that forms ascending tracts.
2. *Motor neurons* include descending fibres from higher centres to the spinal cord and axon of anterior horn cells.
3. *Association fibres* include the fibres that originate and terminate within the spinal cord.

TRACTS OF THE SPINAL CORD

A collection of nerve fibres that connects two masses of grey matter within the central nervous system is called a tract. They are usually named after the masses of grey matter connected by them. Some tracts are called fasciculi or lemnisci.

Classification of Tracts

The tracts of spinal cord are classified into three types (Fig. 5.14):

1. Ascending
2. Descending
3. Intersegmental.

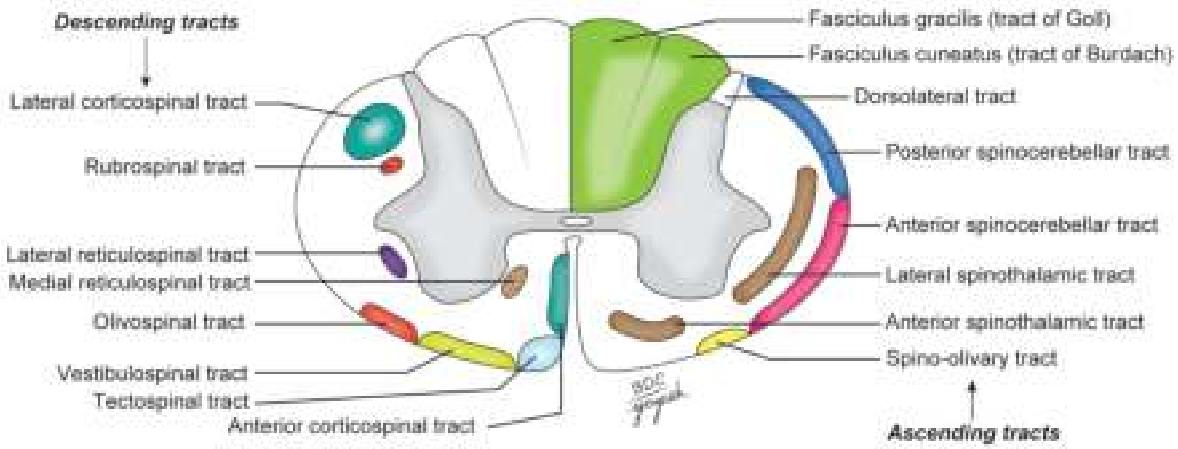

Descending tracts
Lateral corticospinal tract
Rubrospinal tract
Lateral reticulospinal tract
Medial reticulospinal tract
Olivospinal tract
Vestibulospinal tract
Tectospinal tract
Anterior corticospinal tract
Fasciculus gracilis (tract of Goll)
Fasciculus cuneatus (tract of Burdach)
Dorsolateral tract
Posterior spinocerebellar tract
Anterior spinocerebellar tract
Lateral spinothalamic tract
Anterior spinothalamic tract
Spino-olivary tract
Ascending tracts

Fig. 5.14: Main descending (motor) tracts in the left half and ascending (sensory) tracts in the right half (transverse section of the spinal cord at mid-cervical region)

Locations of Tracts in Spinal Cord

The tracts are located in the white matter of the spinal cord as follows:

Anterior white column:

- *Ascending tracts*: Anterior spinothalamic
- *Descending tracts*: Anterior corticospinal, vestibulospinal, tectospinal, medial rubrospinal.

Lateral white column:

- *Ascending tracts*: Lateral spinothalamic, anterior spinocerebellar, posterior spinocerebellar, spinotectal.
- *Descending*: Lateral corticospinal, rubrospinal, lateral reticulospinal, hypothalamospinal.

Posterior white column:

Ascending tracts (*only*): Tract of Goll (fasciculus gracilis), tract of Burdach (fasciculus cuneatus).

Competencies:

AN57.3 Draw and label transverse section of spinal cord at midcervical and midthoracic level.

AN57.4 Enumerate ascending and descending tracts at mid thoracic level of spinal cord.

DESCENDING TRACTS

The descending tracts are of two types: Pyramidal and extrapyramidal (Table 5.5).

Pyramidal or Corticospinal Tracts

Components

It consists of two fibres:

1. *Corticospinal fibres* that terminate at the anterior horn cells of spinal cord.
2. *Corticonuclear fibres* that terminate at the motor nuclei of cranial nerves in the brainstem.

Composition

Pyramidal tract consists of two neurons: Upper and lower (Fig. 5.15). The upper motor neurons are located in motor area (area 4) and premotor area (area 6) of the cerebral cortex. *Motor area* lies in front of central sulcus (precentral gyrus). This area contains giant *pyramidal cells*.

Note: Body is represented upside down in the motor cortex. Leg area is situated uppermost extending on to the medial surface of paracentral lobule. The leg area is followed by thigh, trunk, upper limb, face larynx, lips, jaw, tongue, and pharynx area.

Pathway (Fig. 5.15)

Upper motor neurons

1. The fibres of pyramidal tract originate from the large *pyramidal cells* (UMN) of the motor area.
2. Their axons run in a fan-shaped manner as *corona radiata*. Then these fibres converge and pass through the genu and posterior limb of *internal capsule*.
3. *In midbrain*: Then these fibres pass through the middle three-fifths of the *crus cerebri of midbrain*.

TABLE 5.5: The descending tracts

Name	*Function*	*Crossed and uncrossed*	*Beginning*	*Termination*
Pyramidal tracts				
Lateral corticospinal	Main motor tract for skillful voluntary movements	Crosses in medulla	Motor area of cortex (areas 4, 6)	Anterior grey column cells (alpha motor neurons)
Anterior corticospinal	Facilitates flexors	Crosses in corresponding spinal segment	Motor area of cortex (areas 4, 6)	Anterior grey column cells (alpha motor neurons)
Extrapyramidal tracts				
Tectospinal	Efferent pathway for visual reflexes	Crossed	Superior colliculus	Alpha and gamma motor neurons of anterior grey column cells
Rubrospinal	Efferent pathway for cerebellum and corpus striatum	Crossed	Red nucleus of midbrain	Alpha and gamma motor neurons of anterior grey column cells
Medial reticulospinal	Extrapyramidal tract Facilitates extensors	Uncrossed	Reticular formation of grey matter of pons	Alpha and gamma motor neurons of anterior grey column cells
Lateral reticulospinal	Extrapyramidal tract Facilitates flexors	Uncrossed and crossed	Reticular formation of grey matter of medulla oblongata	Alpha and gamma motor neurons of anterior grey column cells
Lateral vestibulospinal	Efferent pathway for equilibratory control	Uncrossed	Lateral vestibular nucleus	Alpha and gamma motor neurons of anterior grey column cells
Olivospinal	Extrapyramidal tract	Uncrossed	Inferior olivary nucleus	Alpha and gamma motor neurons of anterior grey column cells

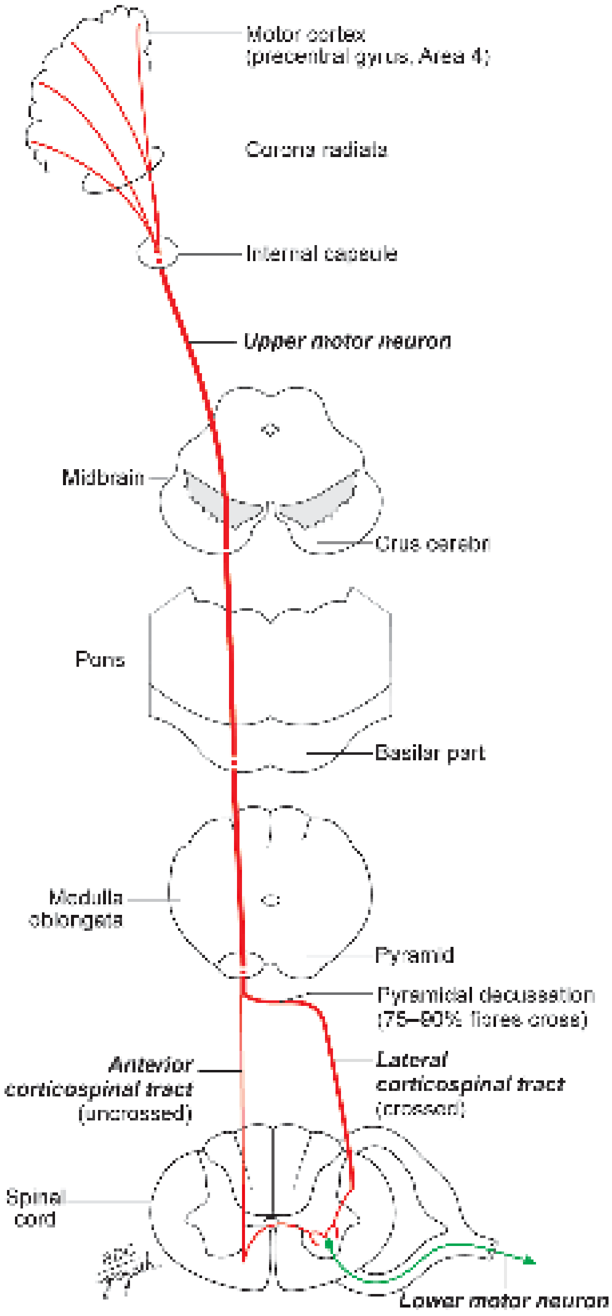


Fig. 5.15: Pyramidal/corticospinal tracts—course of corticospinal fibres

4. *In pons*: These fibres are broken up into number of small bundles by pontine nuclei and transversely running *pontocerebellar fibres* in the basilar part of the pons.
5. *In medulla oblongata*: These fibres converge to form a compact bundle that descends as *pyramid* on each side of the midline. In the lower part of the medulla oblongata, majority of the fibres (75–90%) cross to the opposite side in the *pyramidal decussation* and descends as ***lateral corticospinal*** **(crossed tract) tract**. Remaining fibres continue as ***ventral corticospinal tract*** [*Reference*: *Grey's Anatomy*, *42nd edn*].
6. *In spinal cord*: The lateral corticospinal tract runs in the lateral white column and terminates on the anterior horn cells through interneurons. The ventral corticospinal tract runs in the anterior white column. Its fibres cross to the opposite side in the anterior white commissure of the spinal cord at the level of their termination.

Lower motor neurons

They lie in the *anterior horn of spinal cord*. They receive the impulse from upper motor neurons through interneurons (only 5% upper motor neurons end directly on the lower motor neuron). Axons of lower motor neurons reach the skeletal muscle through the *anterior root of spinal nerves*. They produce contraction of skeletal muscles.

Functional Significance

1. The cerebral cortex controls gross and fine skilled voluntary movements of opposite half of body through anterior horn cells.
2. Influence of this tract is supposed to be facilitatory for flexors and inhibitory for extensors.
3. Anterior corticospinal tract controls voluntary gross movement like walking and running.
4. Corticospinal tract facilitates superficial reflexes and muslce tone.
5. Actions of basal ganglia and cerebellum are mediated by corticospinal tracts.

Extrapyramidal Tracts

These are (Figs 5.16 and 5.17, Table 5.5):

1. Rubrospinal tract
2. Medial reticulospinal tract
3. Lateral reticulospinal tract
4. Olivospinal tract
5. Vestibulospinal tract
6. Tectospinal tract.

Note: The extrapyramidal fibres arise from cortical and subcortical area influence the activity at the anterior horn cell (lower motor neurons). The fibres from cortical centres form synapse with subcortical centre which later send fibres to the spinal cord.

Extrapyramidal pathway: Cortical centres → subcortical centres → spinal cord

Phylogenetically, extrapyramidal system is older than pyramidal system. Extrapyramidal pathway is polysynaptic.

Tectospinal tract (Fig. 5.17): The tract is formed by the axons of neurons lying in the superior colliculus of the midbrain. The fibres cross to the opposite side thus forming *dorsal tegmental decussation* in midbrain. The tract descends through pons, medulla and anterior white column of spinal cord. The fibres terminate on the cells of anterior horn through internuncial neurons. It mediates reflex movements of head and neck in response to visual stimulus.

All these descending tracts control the voluntary movements of skeletal muscles of the body through anterior horn cells directly or through internuncial neurons. The influence is on both alpha and gamma neurons. Gamma neurons also affect alpha neurons through muscle spindles. So, all influences finally reach alpha neurons.

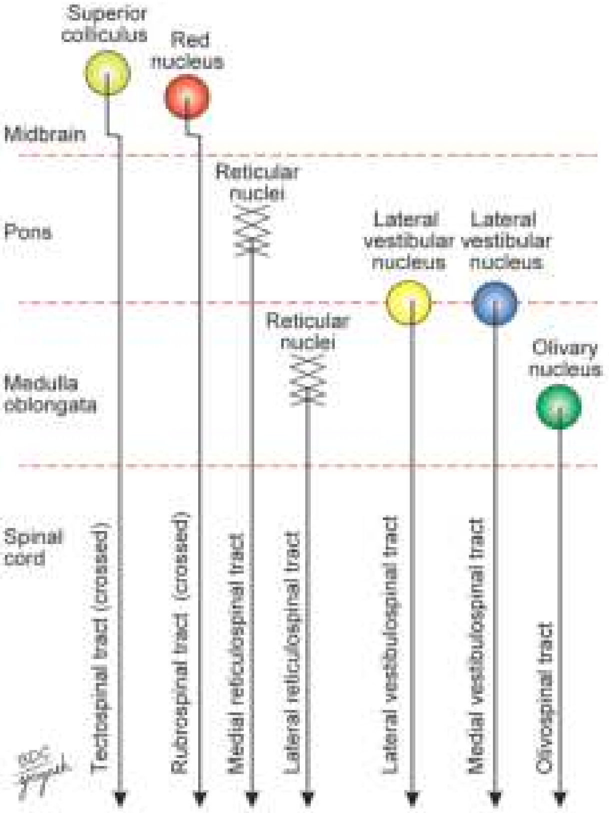

Superior colliculus
Red nucleus
Midbrain
Reticular nuclei
Pons
Lateral vestibular nucleus
Lateral vestibular nucleus
Reticular nuclei
Olivary nucleus
Medulla oblongata
Spinal cord
Tectospinal tract (crossed)
Rubrospinal tract (crossed)
Medial reticulospinal tract
Lateral reticulospinal tract
Lateral vestibulospinal tract
Medial vestibulospinal tract
Olivospinal tract
BDC

Fig. 5.16: Extrapyramidal tracts

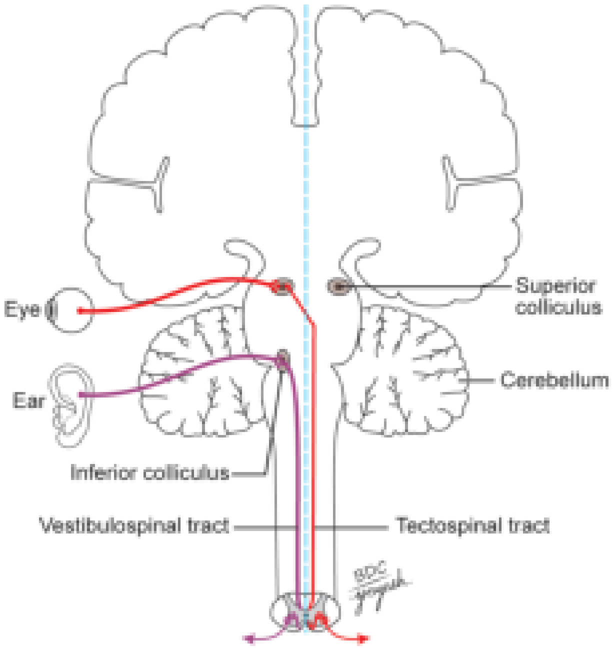

Eye
Superior colliculus
Ear
Cerebellum
Inferior colliculus
Vestibulospinal tract
Tectospinal tract
BDC

Fig. 5.17: Tectospinal and vestibulospinal tracts

Rubrospinal tract: This tract is formed by the axons of red nucleus, situated in the midbrain. The fibres cross with the fibres of the opposite side in the tegmentum of midbrain; thus constituting the *ventral tegmental decussation*. The tract descends through the pons and medulla oblongata and enters the lateral white column of spinal cord. The fibres terminate by synapsing through internuncial neurons with anterior horn cells (Fig. 5.17). It controls the tone of limb flexor muscles by being excitatory to motor neurons of these muscles.

Medial reticulospinal tract: The medial reticulospinal tract is formed by the fibres from reticular formation in pons and descends to the cervical segments only. It lies in the anterior white column of spinal cord. It has uncrossed fibres (Fig. 5.16). It influences voluntary movement, reflex activity and muscle tone by controlling the activity of both alpha and gamma neurons.

***Lateral reticulospinal tract*:** The lateral reticulospinal tract originates from reticular formation in brainstem (midbrain, pons and medulla oblongata) and descends up to thoracic segments of spinal cord. It has both crossed and uncrossed fibres. It lies in the anterolateral white column of spinal cord. Both the tracts terminate by synapsing with the neurons in lamina VII of the spinal cord.

Vestibulospinal tract (Figs 5.16 and 5.17): The fibres arise from lateral vestibular nucleus lying at pontomedullary junction. The fibres descend uncrossed to spinal cord. This tract is situated in the anterior white column of spinal cord. These fibres synapse with anterior horn cells. It has two types:

a. *Lateral*—controls extensors muscle tone
b. *Medial*—for movement of head.

Olivospinal tract: Its fibres originate from the inferior olivary nucleus in medulla oblongata, descend to spinal cord, lie in the anterolateral column of white matter and synapse with the anterior horn cells. It controls activity of motor neurons in spinal cord.

Pyramidal and extrapyramidal tracts have been compared in Table 5.6.

CLINICAL NEUROANATOMY

Lesions of pyramidal tract: The lesions of pyramidal tract divided into two groups:

1. Lesions of upper motor neuron
2. Lesions of lower motor neuron.

Lesions of upper motor neuron: The lesions cause upper motor neuron paralysis which results into hemiplegia and cranial nerve paralysis based on the location of the lesions as follows:

1. *Lesion of motor cortex and internal capsule*: It results in contralateral hemiplegia and contralateral paralysis of lower face and tongue.
2. *Lesion in midbrain*: It results in contralateral hemiplegia and ipsilateral ocular muscles paralysis supplied by III cranial nerve.
3. *Lesion in pons*: It results in:
   i. Raymond syndrome – contralateral hemiplegia and ipsilateral paralysis of lateral rectus (supplied by cranial nerve VI)
   ii. Millard-Gubler syndrome – crossed facial paralysis
4. *Lesion in medulla oblongata* → crossed hypoglossal paralysis
5. *Lesion in spinal cord* → Brown-Séquard syndrome.

TABLE 5.6: Comparison of pyramidal and extrapyramidal tracts

Pyramidal tracts	*Extrapyramidal tracts*
Recent in evolution	Older in evolution
These comprise only cortico-spinal and corticonuclear tracts	These comprise olivospinal, vestibulospinal, tectospinal, reticulospinal, rubrospinal tracts
Origin from motor cortex	These arise from olivary vestibular, tectum (collicular), reticular and red nuclei
The impulse passes directly to anterior horn cells	Impulse passes by polysynaptic route via cortex, basal ganglia, cerebellum and brainstem
Function is to perform voluntary skilled movement	Control tone and equilibrium. These facilitate/inhibit flexor/extensor reflexes
Injury leads to increased muscle tone and loss of motor activity	Injury leads to increased muscle tone with clasp knife rigidity

Features of upper motor lesions: The lesions of upper motor neurons produce the following effects:

1. *Spastic paralysis*: The lower neurons get hyper stimulated by extrapyramidal fibres after losing control of pyramidal fibres. These hyper stimulated LMN cause hypertonia or spasticity of muscle and exaggerated tendon reflexes.
2. *Positive Babinski sign*: On scratching skin of the foot along the lateral aspect of the sole with a blunt object, the great toe undergoes dorsiflexion and other toes fan outward. This is called positive Babinski's sign.
3. Absence of abdominal and cremasteric reflex.

Lesion of lower motor neurons: It involves:

1. Lesions of motor nuclei of cranial nerve
2. Lesions of anterior horn cells of spinal cord
3. Lesions of ventral root or spinal nerves.

It results in:

1. Flaccid type of muscle paralysis with loss of muscle tone
2. Muscle wasting (atrophy)
3. Loss of all reflexes
4. Absence of Babinski's sign.

- The differences between upper and lower motor neuron paralysis are listed in Table 5.7.

ASCENDING TRACTS

The ascending tracts carry the sensory input to the central nervous system. They carry the following sensations:

1. Pain and temperature sensation
2. Fine touch and conscious proprioception
3. Unconscious proprioception.

The ascending tracts include:

1. Lateral spinothalamic tract
2. Anterior spinothalamic tract
3. Fasciculus gracilis (medially)
4. Fasciculus cuneatus (laterally)
5. Dorsal or posterior spinocerebellar tract
6. Ventral or anterior spinocerebellar tract
7. Spino-olivary tract
8. Spinotectal tract.

TABLE 5.7: Differences between upper and lower motor neuron paralysis

Feature	*UMN lesion*	*LMN lesion*
Lesion	Above the anterior horn cells of spinal cord and cranial nerve nuclei	Lesion of anterior horn cells of spinal cord and cranial nerve nuclei
Paralysis	Spastic paralysis	Flaccid paralysis
Muscle tone	Increased	Decreased
Extent of paralysis	Widespread	Localized
Deep tendon reflexes	Increased	Absent
Superficial reflexes	Absent	Absent
Babinski's sign	Extensor (upgoing toe)	Normal or absent
Muscle wasting	Late	Usually present
Muscle clonus	Present	Absent

General Arrangements of Sensory Pathway

The sensory pathways connect sensory receptors with cerebral cortex. Each sensory pathway consists of multiple neurons which are called first order, second order, and third order neurons.

First order neurons: These are located in dorsal root ganglia of spinal nerves and ganglia of cranial nerves. They are pseudounipolar neurons. These neurons have two processes:

1. Peripheral process that carries signal from receptors.
2. Central process that enters the central nervous system and transfers the signal to the second order neurons.

Second order neurons: They are located within the grey matter of spinal cord and brainstem. Axons of most of the second order neurons cross to opposite side and then ascend upward. Some of the primary order neurons transfer the signals to motor neurons (anterior horn cells) to generate the reflexes.

Third order neurons: They are present in ventral postero-lateral nucleus of thalamus. Their axons transfer the signals to sensory area of the cerebral cortex.

Lateral Spinothalamic Tract

The lateral spinothalamic tract carries *pain and temperature* sensations from opposite side of the body (Fig. 5.18).

Receptors:

For pain: Free nerve endings

For temperature:

- End bulbs of Krause for cold
- End bulbs of Ruffini for warmth.

Location in spinal cord: Lateral white column.

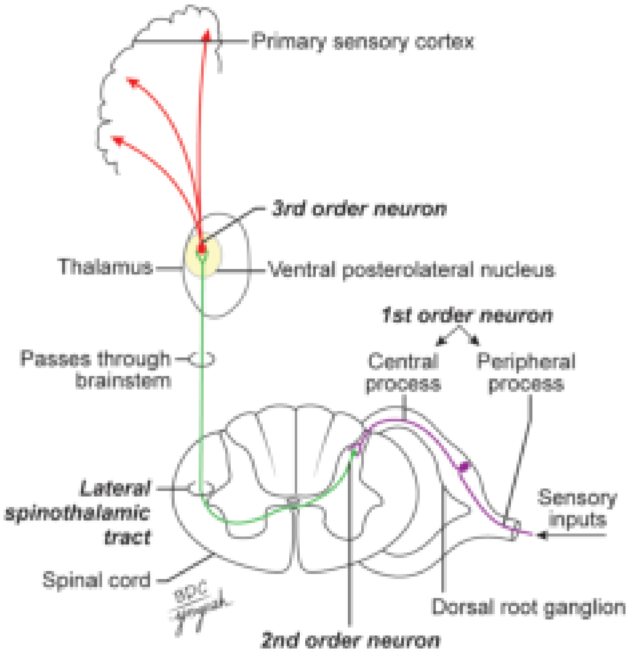

Primary sensory cortex
3rd order neuron
Thalamus
Ventral posterolateral nucleus
1st order neuron
Passes through brainstem
Central process
Peripheral process
Lateral spinothalamic tract
Sensory inputs
Spinal cord
Dorsal root ganglion
2nd order neuron

Fig. 5.18: Lateral spinothalamic tract

Composition/Pathway

It consists of three order neurons: First order, second order, and third order neurons.

1. ***First-order neurons:*** These are pseudounipolar neurons of the dorsal root ganglia of spinal cord that has:
   a. *Peripheral processes* that carry pain and temperature sensations through the spinal nerve and its dorsal root.
   b. *Central processes* that enter the spinal cord through the lateral division of dorsal root of spinal nerve.

   These fibres ascend upward for one or two segments as *dorsolateral tract of Lissauer* (at the tip of dorsal horn). They relay in posterior horn by synapsing with neurons of *substantia gelatinosa*.
2. ***Second-order neurons:*** The cells of dorsal horn form the second order neurons. Their axon cross to the opposite side in anterior white commissure and ascends upward in the opposite white column as lateral spinothalamic tract. They ascend as *spinal lemniscus* in brainstem. They terminate in the ventral posterolateral nucleus (VPL) of thalamus.
3. ***Third-order neurons:*** These are neurons of ventral posterolateral nucleus (VPL) of thalamus. Their axons project to the *primary sensory cortex* of the cerebral hemisphere. These fibres pass through the posterior limb of the internal capsule.

Note: In the lateral spinothalamic tract, pain fibres are located anteriorly, while temperature fibres are located posteriorly. The fibres are arranged superficial to deep as sacral, lumbar, thoracic, and cervical. The fibres of lateral spinothalamic tract form *spinal lemniscus* in the brainstem. Pain and perhaps temperature reach consciousness at thalamic level and emotional responses are elicited. Precise source, severity, quantity of pain and temperature stimuli, the cerebral cortex play an important role.

CLINICAL NEUROANATOMY

- *Unilateral lesion of lateral spinothalamic tract* → complete loss of pain and temperature sensations on the opposite side of the body.
- ***Cordotomy*** *for pain relief*: Cordotomy is a surgical procedure. In this procedure lateral spinothalamic tract is severed (incised) to relieve intractable pain.
  Anatomical basis: The fibres carrying pain lie on the lateral side in lateral spinothalamic tract (in lateral white column).
- ***Syringomyelia***: In syringomyelia, crossing fibres of lateral spinothalamic tract are compressed that cause bilateral loss of pain and temperature sensation below the level of lesion.

Anterior Spinothalamic Tract

It carries the following sensations from opposite side of the body (Fig. 5.19):

- light touch, tickle, itch
- pressure.

Receptors:

- Merkel's disc, nerve ending at hair root, Meissner's corpuscles
- for touch
- Pacinian corpuscles – for pressure.

Location in spinal cord: Anterior white column.

Composition/Pathway

It consists of three order neurons: First, second, and third.

First order neurons: These are pseudounipolar neurons of the spinal cord that has:

a. *Peripheral processes* that carry the sensation through the spinal nerve and its dorsal root.

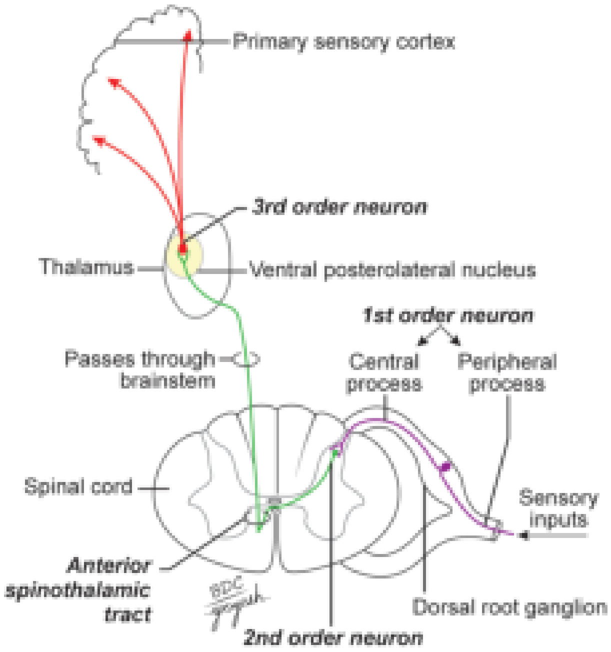

Primary sensory cortex
3rd order neuron
Thalamus
Ventral posterolateral nucleus
1st order neuron
Passes through brainstem
Central process
Peripheral process
Spinal cord
Sensory inputs
Anterior spinothalamic tract
Dorsal root ganglion
2nd order neuron

Fig. 5.19: Anterior spinothalamic tract

b. *Central processes* are highly myelinated. They enter the spinal cord through medial division of the dorsal root of spinal nerve. On entering the spinal cord, they ascend one to two segments in a dorsolateral tract of Lissauer. They relay at the cells of substantia gelatinosa.

Second order neurons: They are located in the dorsal horn of spinal cord (in the substantia gelatinosa) their axons cross the midline in the anterior white commissure to reach the contralateral anterior white column. Then they ascend upward as anterior spinothalamic tract just in front of anterior horn. They ascend as *spinal lemniscus* in brainstem. These neurons relay in the ventral posterolateral nucleus (VPL) of the thalamus.

Third order neurons: These are neurons of ventral posterolateral nucleus (VPL) of thalamus. Their axons project to the *primary sensory cortex* of the cerebral hemisphere. These fibres pass through the posterior limb of the internal capsule.

CLINICAL NEUROANATOMY

- *Lesion of anterior spinothalamic tract* → little or no loss of tactile, touch and pressure sensations as these are also transmitted by fasciculus gracilis and cuneatus.
- ***Dissociation anaesthesia***: It indicates the loss of pain and temperature sensations without affecting touch sensation.

  Anatomical basis: In syringomyelia, it affects the second order neurons that cross the midline. They are as follows:
  - Fibres of lateral spinothalamic tract – loss of pain and temperature sensations
  - Fibres of anterior spinothalamic tract – no or little loss of touch sensation as it is carried by uncrossed dorsal white column tract, fasciculus gracilis and cuneatus.

Note: ***Jacket type anaesthesia*** for pain and temperature: In syringomyelia, there is compression of crossing fibres of lateral spinothalamic tract (carry pain and temperature) at the level of lesion. It causes loss of pain and temperature sensations at the level of lesion, but not above and below the lesion. This produces a jacket-type of anaesthesia for pain and temperature.

Tract of Goll and Tract of Burdach

Synonym: Fasciculus gracilis and fasciculus cuneatus (Fig. 5.20).

They carry the following sensations from opposite side of the body:

- Fine touch, two-point discrimination
- Vibration
- *Conscious proprioception*: Joint sense, stereognosis, conscious kinesthesia.

Location: Posterior white column.

Receptors:

- Meissner's corpuscles – for fine touch
- Pacinian corpuscles and free nerve endings – for vibration and proprioception.

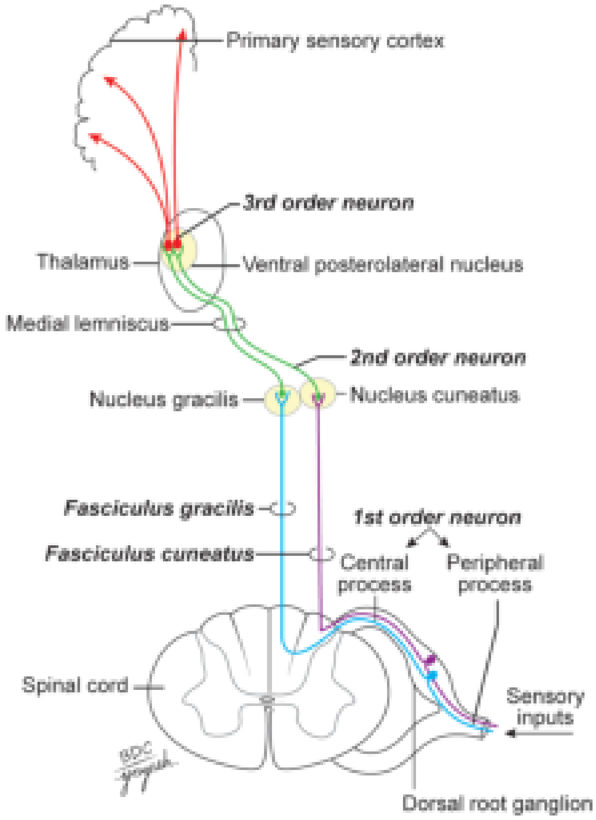


Fig. 5.20: Fasciculus gracillis and fasciculus cuneatus

Composition/Pathway

First order neurons: These are pseudounipolar neurons of the spinal cord that has:

a. *Peripheral processes* that carry the sensation through the spinal nerve and its dorsal root.

b. *Central processes* are thickly myelinated. They enter the spinal cord through median division of the spinal roots of spinal nerves.

Then they ascend upward in the posterior column as follows:

Fasciculus gracilis – fibres from coccygeal, sacral, lumbar, and lower thoracic regions form fasciculus gracilis.

Fasciculus cuneatus – fibres from upper thoracic and cervical regions form fasciculus cuneatus.

Arrangements of fibre lateral to medial: Cervical, thoracic, lumbar, and sacral fibres.

Fasciculus gracilis terminates at the nucleus gracilis and fasciculus cuneatus at the nucleus cuneatus.

Note: Fasciculus gracilis lies medial to the fasciculus cuneatus in the posterior white column. They are separated from each other by posterointermediate sulcus and septum. The fibres in the spinal cord which enter in the coccygeal and lower sacral region are thrust medially by fibres which enter at higher levels (Figs 5.20 and 5.21).

Second order neurons: The neurons of nuclei gracilis and cuneatus form second order neurons. Their axons curve ventromedially as *internal arcuate fibres* which decussate (cross) to the opposite side and ascend upward as ***medial lemniscus***. These nuclei lie on the posterior aspect of medulla oblongata. Then medial

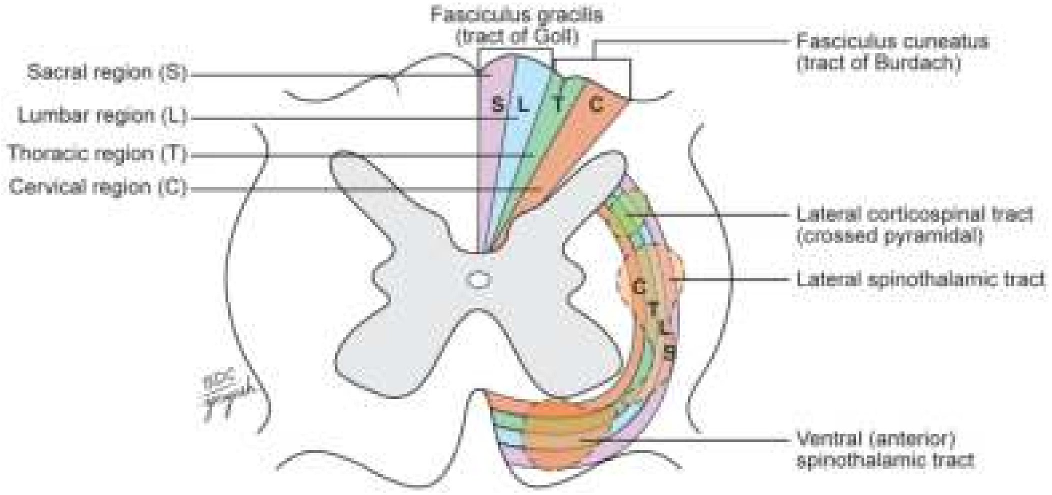

Fasciculus gracilis (tract of Goll)
Fasciculus cuneatus (tract of Burdach)
Sacral region (S)
Lumbar region (L)
Thoracic region (T)
Cervical region (C)
S
L
T
C
Lateral corticospinal tract (crossed pyramidal)
Lateral spinothalamic tract
C
T
L
S
Ventral (anterior) spinothalamic tract

Fig. 5.21: Somatotopic lamination of tracts in the spinal cord

lemniscus ascends in pons and midbrain to terminate in *ventral posterolateral nucleus of thalamus*.

Third order neurons: They are located in VPL nucleus thalamus. Their axons ascend through the posterior limb of internal capsule and terminate in the sensory cortex of cerebral hemisphere.

CLINICAL NEUROANATOMY

- Unilateral lesion of posterior white column → results in loss of the discriminatory touch, sense of position, and vibration sensations below the level of lesion and on the side of lesion.
- ***Tabes dorsalis***: In syphilis, the posterior white column undergoes degenerative changes. These are called tabes dorsalis. It results in loss of position, vibration, and two-point discrimination sensations.
- ***Romberg's sign***: In positive Romberg's sign, the patient falls if he stands with feet together and eyes closed. It may occur due to damage to tract of Goll and Burdach (loss of position sense).

Spinocerebellar Tracts

The spinocerebellar tracts carry the unconscious proprioception to the cerebellum. They form afferent fibres of reflex arc involving cerebellum for maintenance of posture and coordination of movement.

Receptors: Stretch receptor of muscle spindle and Golgi tendon organ for unconscious proprioception.

Composition/Pathway

The spinocerebellar tract consists of two neurons arrangement. The spinocerebellar tracts include (Fig. 5.22 and Table 5.8):

1. Dorsal spinocerebellar tract
2. Ventral spinocerebellar tract
3. Cuneocerebellar tract
4. Rostral spinocerebellar tract.

Posterior (Dorsal) Spinocerebellar Tract

First order neurons: They are pseudounipolar neurons of dorsal root ganglion. Their central processes enter the spinal cord and relay in Clarke's column.

Second order neurons: They are located *in nucleus dorsalis* (*Clarke's column*). Their axons pass to the dorsolateral part of lateral white column of same side and ascend as dorsal tract of spinocerebellar tract.

They ascend to medulla oblongata where they enter *inferior cerebellar peduncle* and terminates in the ipsilateral cerebellar cortex (vermis).

Anterior (Ventral) Spinocerebellar Tract

First order neurons: The location and course of first order neurons are similar to dorsal spinocerebellar tract.

Second order neurons: They are located in laminae V–VII of lumbosacral segments of spinal cord. Their axons mostly decussate (cross) and ascend as anterior or ventral spinocerebellar tracts in the anterolateral part of lateral white column. They ascend to midbrain and enter the cerebellum through *superior cerebellar peduncle*. They decussate in the cerebellum and terminate in the cerebellum cortex (vermis).

Cuneocerebellar Tract

First order neuron: They are located in the dorsal root ganglion. Their central processes enter the spinal cord at C2 to T5 level and ascend in fasciculus cuneatus in posterior white column. They terminate in internal or *accessory cuneate nucleus*. It is similar to nucleus dorsalis of Clarke which is present in the thoracic region.

Second order neurons: They are located in the accessory cuneate nucleus. Their axons join the restiform body or *inferior cerebellar peduncle* and relay in the ipsilateral cerebral cortex.

Note: Clarke's column is not present above C8 level, hence ventral and dorsal spinocerebellar tracts are replaced by cuneocerebellar tract which carries unconscious proprioception from the neck, upper limb and upper part of the trunk.

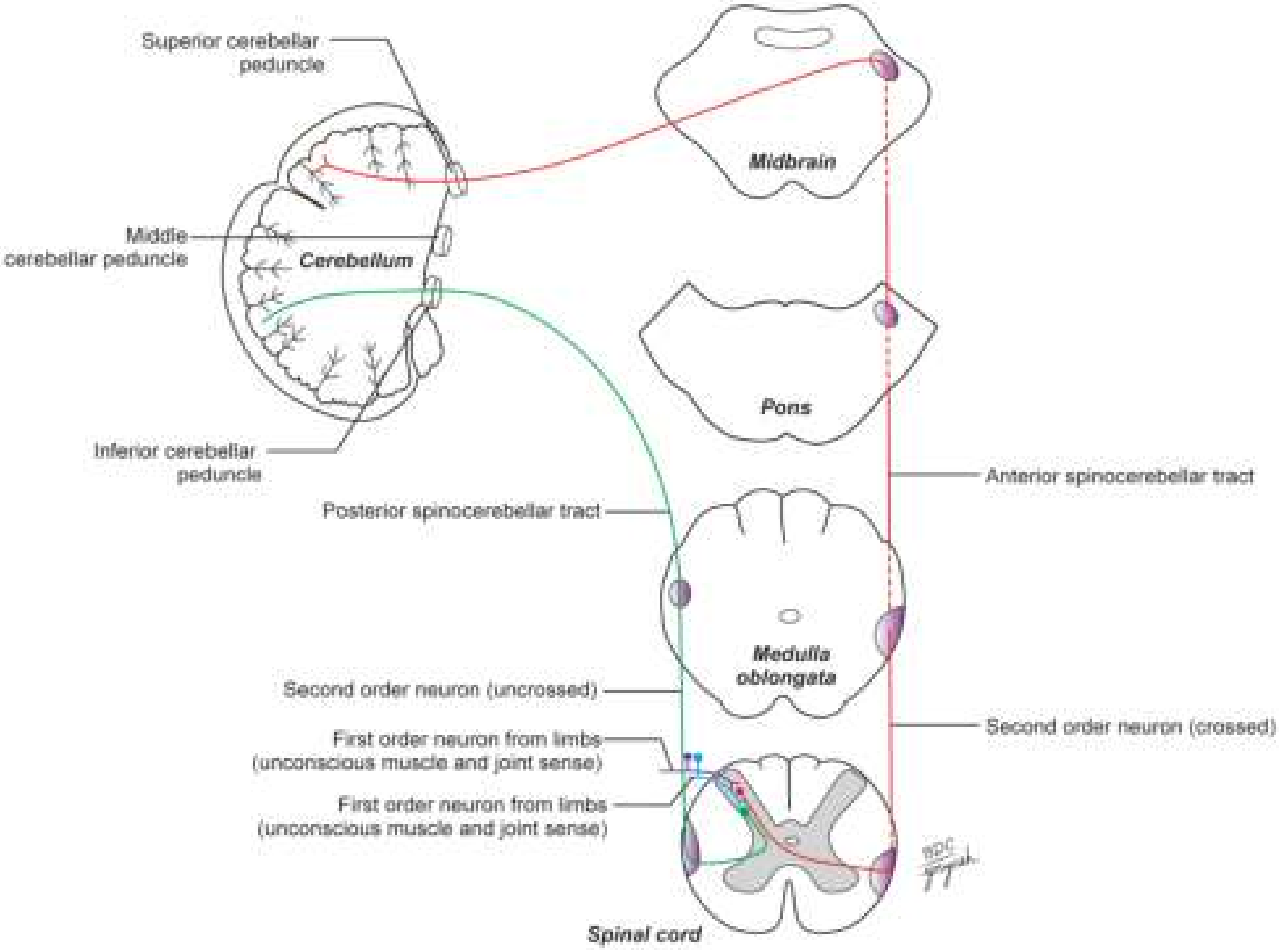

Superior cerebellar peduncle
Middle cerebellar peduncle
Cerebellum
Inferior cerebellar peduncle
Posterior spinocerebellar tract
Second order neuron (uncrossed)
First order neuron from limbs (unconscious muscle and joint sense)
First order neuron from limbs (unconscious muscle and joint sense)
Spinal cord
Midbrain
Pons
Anterior spinocerebellar tract
Medulla oblongata
Second order neuron (crossed)

Fig. 5.22: Pathway of posterior and anterior spinocerebellar tracts

TABLE 5.8: Spinocerebellar tracts

Tract	*First order neuron*	*Second order neuron*	*Termination*	*Functions*
Dorsal or posterior spinocerebellar tract (C8 to L3)	Cells of dorsal root ganglion	Cells of dorsal nucleus (Clark's column)	Ipsilateral cerebellar vermis	• Proprioception from ipsilateral trunk and lower limb • Coordination of movements of lower limb • Maintenance of posture
Ventral or anterior spinocerebellar tract (C8–L3)	Cells of dorsal root ganglion	Dorsal horn cells	Ipsilateral cerebellar vermis	• Proprioception from ipsilateral trunk and lower limb • Same as above
Cuneocerebellar (C2 to T5)	Dorsal root ganglion	Accessory cuneate nucleus	Ipsilateral cerebellar vermis	Proprioception from ipsilateral neck and upper limb
Rostral spinocerebellar (C4–C8)	Dorsal root ganglion	Dorsal horn cells	Cerebellum	Proprioception from ipsilateral head and upper limb

Rostral Spinocerebellar Tract

First order neurons: These are the dorsal horn cells (C4–C8) that give information of unconscious proprioception of head and upper limb. Their central processes terminate in the lamina VII of dorsal horn.

Second order neurons: They are located in *lamina VII of dorsal horn at C4 to C8 level*. Their axons ascend as rostral spinocerebellar tract along with ventral spinocerebellar tract. They enter the cerebellum mostly through *inferior cerebellar peduncle* (few through superior cerebellar peduncle) and terminate in cerebellar cortex.

INTERSEGMENTAL TRACTS

These are formed of fibres connecting various segments of spinal cord. These are present in anterior, posterior and lateral columns of white matter adjacent to the grey matter of spinal cord. Tract of Lissauer is also an intersegmental tract.

Competency:

AN57.5 Describe the anatomical basis of clinical conditions affecting the grey and white matter of spinal cord (Brown-Séquard syndrome, poliomyelitis, amyotrophic lateral sclerosis or motor neuron disease, syringomyelia, hereditary sensory neuropathy, subacute combined degeneration, transverse myelitis, paraplegia).

CLINICAL NEUROANATOMY

Amyotrophic lateral sclerosis: It is a degenerative disease which is caused due to damage of the cells in the ventral horn. The clinical features involve weakness, atrophy of muscles of hands and arms and later extending to the lower limb.

Subacute combined degeneration: The posterior and lateral funiculi are degenerated bilaterally and it is caused due to deficiency of intrinsic factor which helps in absorption of vitamin B12. The symptoms include upper motor neuron lesion with loss of position and vibratory sensation of lower limbs.

Syringomyelia (central spinal cord syndrome): There is formation of cavities around the central canal usually in the lower cervical region. Its features are:

1. Bilateral loss of pain and temperature occurs due to injury to the decussating fibres of lateral spinothalamic fibres (Fig. 5.23).
2. Bilateral loss of touch occurs due to injury to anterior spinothalamic tract.

Anatomical basis:

1. As the decussation of lateral and anterior spinothalamic tracts occurs at different levels, there is dissociated sensory loss.
2. As this disease occurs in lower cervical and upper thoracic regions, there is problem in both the upper limbs and front of chest.
3. Syringomyelia disrupts the crossing fibres of antero-lateral system. The medial lemniscal system is spared.

Brown-Séquard syndrome: This is caused due to ***hemisection of the spinal cord***. Figure 5.24 shows various features of hemisection on the left side.

Below the level of lesion:

1. Ipsilateral upper motor neuron paralysis caused by pyramidal tract damage.
2. Ipsilateral loss of conscious proprioceptive sensations caused due to damage to posterior white column.
3. Contralateral loss of pain and temperature and touch caused due to damage to lateral spinothalamic and anterior spinothalamic tracts.

At the level of lesion:

1. Ipsilateral lower motor neuron paralysis caused due to damage to ventral nerve roots.
2. Ipsilateral anaesthesia over the skin of the segment due to injury to the ventral nerve roots.

Above the level: Ipsilateral hyperaesthesia above the level of lesion due to irritation of dorsal nerve roots.

Complete transaction of spinal cord: In severe injury, there may be complete transaction of spinal cord. The clinical features are grouped into two phases:

1. ***Stage of spinal shock:*** Immediately after complete transection of the spinal cord, the stage of spinal shock begins. It lasts for first three weeks of injury. It is characterised by:
   - Flaccid paralysis of all muscles
   - Loss of all superficial and deep reflexes below the level of injury.
   - Retention of urine due to loss of relaxation of internal sphincter of urinary bladder and flaccid paralysis of detrusor muscle.

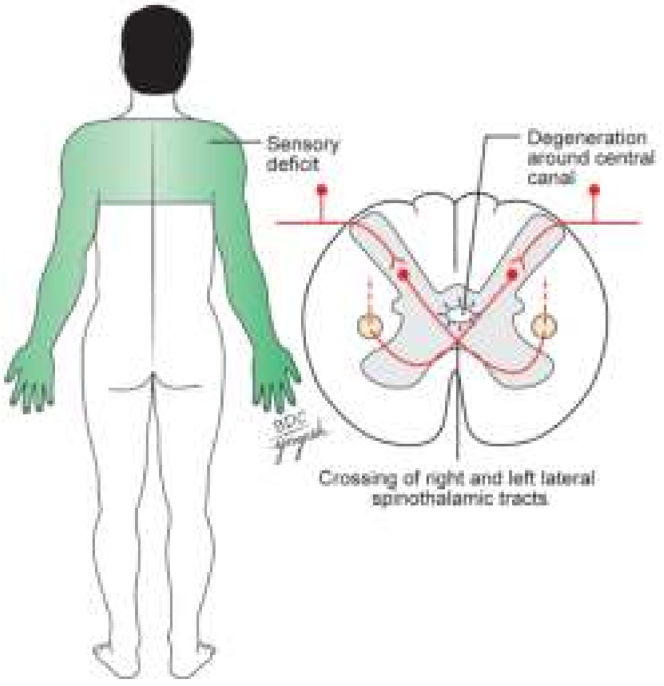

Sensory deficit
Degeneration around central canal
Crossing of right and left lateral spinothalamic tracts

Fig. 5.23: Syringomyelia (central spinal cord syndrome)

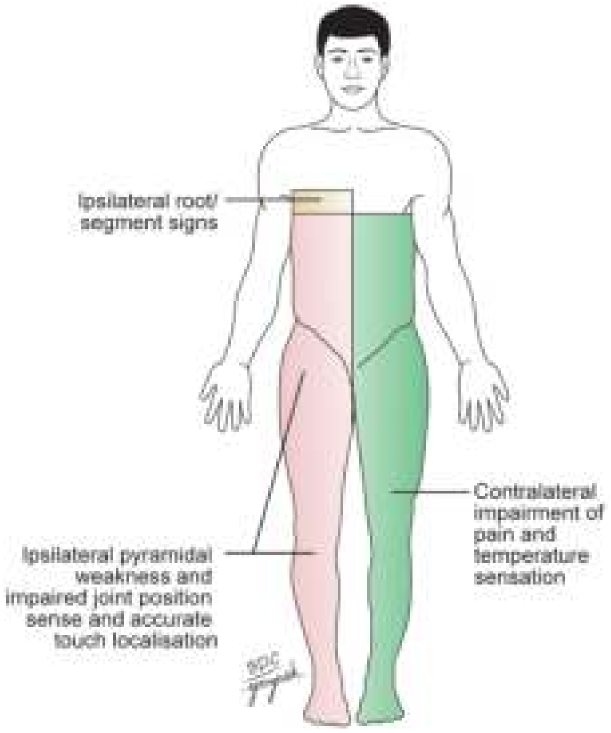

Ipsilateral root/ segment signs
Contralateral impairment of pain and temperature sensation
Ipsilateral pyramidal weakness and impaired joint position sense and accurate touch localisation

Fig. 5.24: Brown-Séquard syndrome

- Retention of faeces due to non-relaxation of external anal sphincter.
- Retention incontinence – that is urine will accumulate until the pressure is high enough to force the urine through the sphincter.

2. ***Recovery phase:*** After the recovery from the shock, the muscle activity reappears. This phase is characterised by:
   - Upper motor neuron, paralysis (spastic) will appear below the level of the lesion as follows:
     - Lesion above C5 spinal segment → respiratory failure due to paralysis of phrenic nerve.
     - Lesion between C2 to T1 → quadriplegia (paralysis of all 4 limbs).
     - Lesion below T1 segments → paraplegia (paralysis of both lower limb).
     - Automatic emptying of urinary bladder and bowel, that is, involuntary emptying at short interval after their sufficient distention.

BLOOD SUPPLY OF SPINAL CORD

Arterial Supply

The spinal cord is supplied by:

1. Anterior spinal artery
2. Posterior spinal arteries (right and left)
3. Spinal branches of vertebral, deep cervical, posterior intercostal, lumbar, and lateral sacral arteries (Fig. 5.25).

Anterior Spinal Artery

Two spinal branches (right and left) arise from the vertebral arteries, arise in front of upper part of medulla oblongata. These branches unite to form a single anterior spinal artery that descends in anterior median fissures of the spinal cord.

Branches: Anterior spinal artery gives:

Central branches – pass through the anterior median fissure into the substance of spinal cord.

Vasa corona (arteriae coronae) – pass along the outer surface of spinal cord and form plexus within the pia mater.

Distribution: Anterior spinal artery supplies:

- Anterior and lateral horn
- Base of posterior horn
- Anterior white column
- Part of lateral white column.

Posterior Spinal Arteries

They arise from vertebral or inferior cerebellar artery. Each posterior spinal artery divides into two longitudinal branches. One descends in front, and another descends behind the dorsal root.

Branches: They give small branches that penetrate and serve the spinal cord.

Distribution: They supply:

- Posterior horn except its base
- Posterior white column
- Peripheral part of lateral white column.

Radicular Arteries

The anterior and posterior spinal arteries are small vessels that cannot sufficiently supply the entire length of spinal cord, especially lower part. Hence, these arteries are reinforced by segmental branches of vertebral, deep cervical, posterior intercostal, lumbar, and lateral sacral arteries. These spinal branches enter the vertebral canal through corresponding *intervertebral foramen* and divides into *anterior and posterior radicular arteries* which reach the spinal cord along the anterior and posterior root of spinal nerves. Radicular arteries reinforce the anterior and posterior spinal arteries.

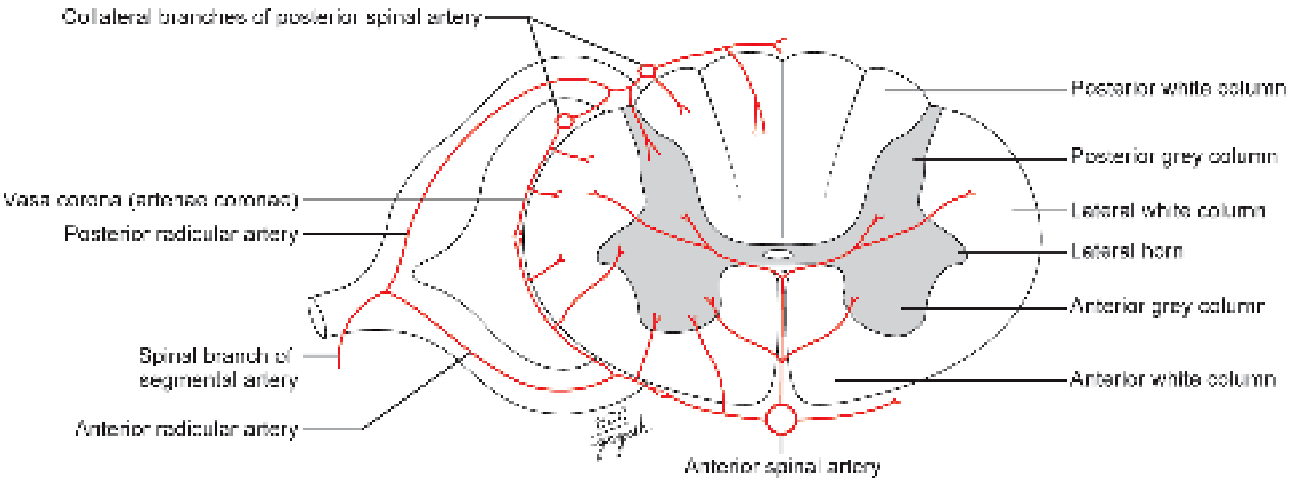
Arteria Radicularis Magna (Artery of Adamkiewicz)

It is the largest radicular artery; usually it lies at T11 segment of spinal cord.

Venous Drainage

The venous blood is drained from the spinal cord by six longitudinal venous channels as follows (Fig. 5.26):

- *Anteromedian longitudinal venous channel* – lies along the anterior median fissure.



Collateral branches of posterior spinal artery
Vasa corona (arteriae coronae)
Posterior radicular artery
Spinal branch of segmental artery
Anterior radicular artery
Anterior spinal artery
Posterior white column
Posterior grey column
Lateral white column
Lateral horn
Anterior grey column
Anterior white column

Fig. 5.25: Arterial supply of spinal cord

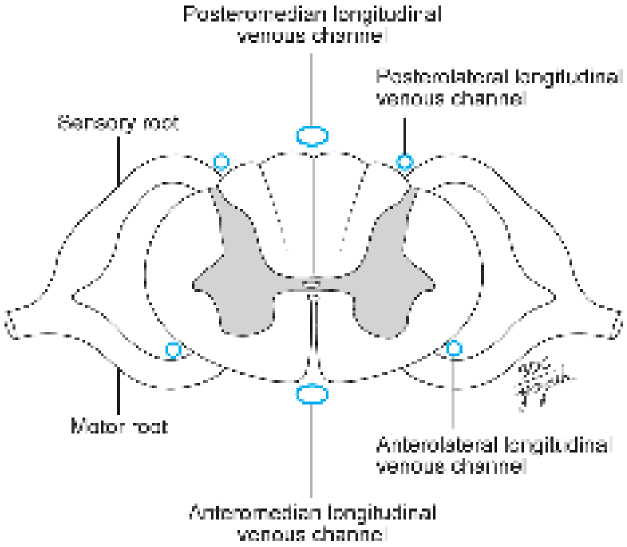

Posteromedian longitudinal venous channel
Posterolateral longitudinal venous channel
Sensory root
Motor root
Anterolateral longitudinal venous channel
Anteromedian longitudinal venous channel

Fig. 5.26: Venous drainage of the spinal cord

- *Posteromedial longitudinal venous channel* – lies along the posterior median sulcus.
- *Pair of anterolateral longitudinal venous channels* – one on each side, behind the ventral root.
- *Pair of posterolateral longitudinal venous channels* – one on each side, behind dorsal nerve root.

These veins lie in the pia matter. They drain into the *internal vertebral venous plexus* and the veins which leave through intervertebral foramen and open into adjacent vertebral, posterior intercostal, lumbar and lateral sacral veins.

CLINICAL NEUROANATOMY

1. ***Transverse myelitis*** is an inflammatory condition affecting both sides of a segment of the spinal cord, leading to sudden weakness, sensory alterations, and loss of bladder or bowel control. It can result from infections, autoimmune disorders, or multiple sclerosis, causing nerve damage and disrupting communication between the brain and the body.
2. ***Subacute combined degeneration*** is a neurological disorder caused by vitamin B12 deficiency, leading to degeneration of the spinal cord's dorsal and lateral columns. It presents with symptoms like weakness, numbness, and impaired coordination. If untreated, it can progress to severe neurological damage, including paralysis, sensory loss, and cognitive changes.
3. ***Hereditary sensory neuropathy*** is a group of genetic disorders that affect sensory nerves, leading to loss of pain, temperature, and touch sensations. Symptoms include numbness, ulcers, and unrecognized injuries, particularly in the hands and feet.
4. ***Amyotrophic lateral sclerosis*** or ***motor neuron disease*** is a progressive neurodegenerative disease affecting motor neurons in the brain and spinal cord. It leads to muscle weakness, paralysis, and loss of voluntary movement, while cognitive function typically remains intact. It gradually impairs breathing and swallowing, ultimately resulting in severe disability and respiratory failure.

Facts to Remember

- Length of spinal cord is 45 cm in adult males.
- Spinal cord ends at L3 vertebra at birth and lower border of L1 or upper border of L2 vertebra in adults.
- Lateral horn is only present in T1–L2 and S2–S4 segments of spinal cord.
- Sympathetic fibres (white ramus communicans) start from lateral horn → ventral root → trunk of spinal nerve → ventral primary ramus → sympathetic ganglion (Fig. 3.7).
- Poliovirus affects the neurons of anterior horn cells of the spinal cord. Polio drops as a vaccine has eradicated the dreadful disease.
- The hemisection of the spinal cord produces Brown-Séquard syndrome.
- Compete transection of spinal cord shows two phases: Stage of spinal shock for first three week and stage of recovery after three weeks.

BDC's Anatomy *e*-book

1. Neuronal columns of grey matter of spinal cord
2. Arrangement of pyramidal tract fibres
3. Extrapyramidal centres
4. Pathway for pain and temperature from head region
5. Proprioception from head
6. Unilateral/partial spinal cord lesion
7. Further reading
8. Viva voce questions

Chapter

6

Cranial Nerves and Special Senses

There are 12 pairs of cranial nerves as follows:

I: Olfactory
II: Optic
III: Oculomotor
IV: Trochlear
V: Trigeminal
VI: Abducent
VII: Facial
VIII: Vestibulocochlear
IX: Glossopharyngeal
X: Vagus
XI: Accessory
XII: Hypoglossal.

Attachment of the nerves to brain is as follows (Fig. 6.1):

I, II to the forebrain.
III, IV to midbrain.
V, VI, VII, VIII to the pons.
IX, X, XI, XII to the medulla oblongata.

Note: During early stages of development, the wall of the neural tube is made up of three layers: inner ependymal layer, middle mantle layer, and the outer marginal layer. The mantle layer represents grey matter and the marginal layer represents the white matter. Soon the mantle layer differentiates into a dorsal alar lamina (sensory) and a ventral basal lamina (motor), the two are partially separated internally by the sulcus limitans.

In the brainstem, the alar and basal laminae of the neural tube come to lie in the same ventral plane because of stretching of the roof plate (dorsal wall) of neural tube by pontine flexure. Further, the grey matter forms separate longitudinal functional columns, where the motor columns (from basal lamina) are medial and the sensory columns (from alar lamina) are lateral in position.

Competency:
AN62.1 Enumerate cranial nerve nuclei with its functional component.

FUNCTIONAL COMPONENTS OF CRANIAL NERVES

The functional component is a part of cranial nerve that performs a specific function, such as:

a. Motor or efferent component and
b. Sensory or afferent component.

These are further classified according to function as follows (Figs 6.2):

Efferent (motor) components (Table 6.1)

1. *General somatic efferent* (*GSE*): They supply striated muscles of head that are not originated from pharyngeal arches.
2. *Special visceral efferent* (*SVE*) or branchial efferent: They supply striated muscles of pharyngeal arches, trapezius, and sternocleidomastoid muscle.
3. *General visceral efferent* (*GVE*) are preganglionic parasympathetic fibres. They supply glands, smooth muscles of viscera and vessels.

Afferent (sensory) components (Table 6.2)

1. *General visceral afferent* (*GVA*): They carry visceral sensation via vagus nerve.
2. *Special visceral afferent* (*SVA*): They carry taste sensation.
3. *General somatic afferent* (*GSA*): They carry proprioception, tactile sensation from face and oral, nasal, and pharyngeal mucosa via trigeminal nerve.
4. *Special somatic afferent* (*SSA*): They carry auditory and vestibular impulse.

Each cranial nerve may carry fibres of one or more components. For example, trochlear nerve carry fibres of somatic efferent column and it supplies muscles developed from cranial somites.

NUCLEI OF CRANIAL NERVES

General Somatic Efferent (GSE) Nuclei (Fig. 6.3)

These nuclei supply skeletal muscle of somatic origin.

1. ***Oculomotor nucleus*** is situated in the midbrain at the level of the superior colliculus. Its fibres enter the oculomotor nerve and supply 5 extrinsic muscles of the eyeball except the lateral rectus and the superior oblique.
2. ***Trochlear nucleus*** is situated in the midbrain at the level of the inferior colliculus. It supplies only the superior oblique muscle through the trochlear nerve.
3. ***Abducent nucleus*** is situated in the lower part of the pons. It supplies only the lateral rectus muscle through the abducent nerve.

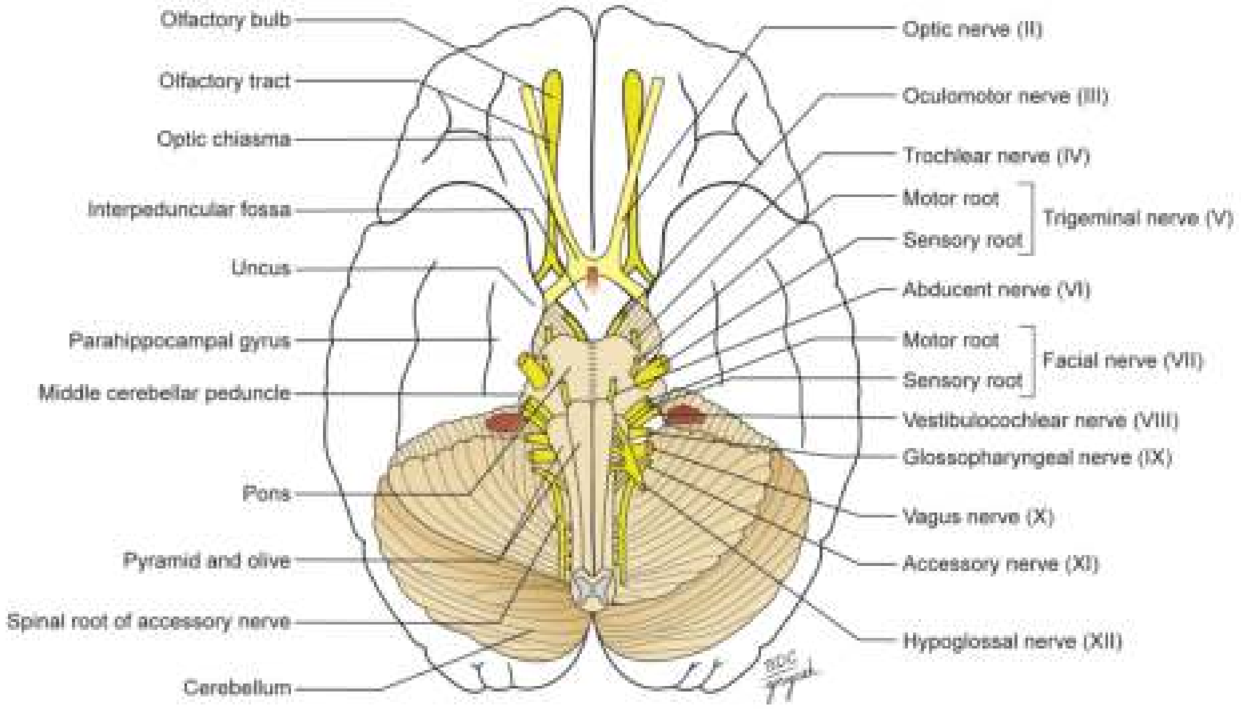

Olfactory bulb
Olfactory tract
Optic chiasma
Interpeduncular fossa
Uncus
Parahippocampal gyrus
Middle cerebellar peduncle
Pons
Pyramid and olive
Spinal root of accessory nerve
Cerebellum
Optic nerve (II)
Oculomotor nerve (III)
Trochlear nerve (IV)
Motor root
Sensory root
Trigeminal nerve (V)
Abducent nerve (VI)
Motor root
Sensory root
Facial nerve (VII)
Vestibulocochlear nerve (VIII)
Glossopharyngeal nerve (IX)
Vagus nerve (X)
Accessory nerve (XI)
Hypoglossal nerve (XII)

Fig. 6.1: Attachment of cranial nerves to the base of brain

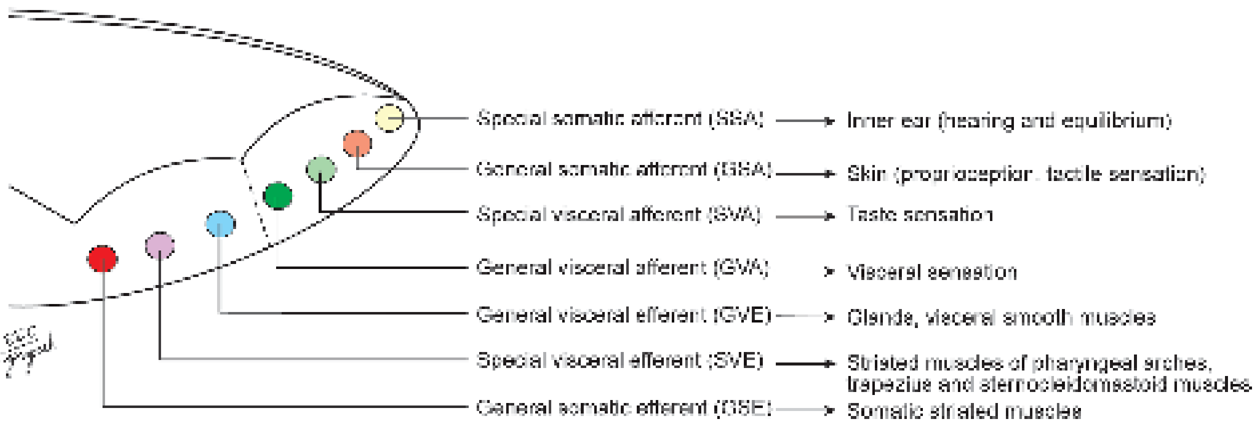

Special somatic afferent (SSA)
Inner ear (hearing and equilibrium)
General somatic afferent (GSA)
Skin (proprioception, tactile sensation)
Special visceral afferent (SVA)
Taste sensation
General visceral afferent (GVA)
Visceral sensation
General visceral efferent (GVE)
Glands, visceral smooth muscles
Special visceral efferent (SVE)
Striated muscles of pharyngeal arches, trapezius and sternocleidomastoid muscles
General somatic efferent (GSE)
Somatic striated muscles

Fig. 6.2: Transverse section of an embryonic brainstem showing the arrangement of functional/nuclear columns of cranial nerve nuclei

TABLE 6.1: Cranial nerve nuclei: Efferent column

	GSE	*SVE*	*GVE*
Functions	Striated muscles of head	Striated muscles of pharyngeal arches	Parasympathetic fibres
Midbrain	Oculomotor nucleus Trochlear nucleus	—	Edinger-Westphal nucleus
Pons	Abducent nucleus	Motor nucleus of Vth nerve and facial nerve	Superior salivatory nucleus Lacrimatory nucleus
Medulla oblongata	Hypoglossal nucleus	Nucleus ambiguus	Inferior salivatory nucleus Dorsal nucleus of vagus

TABLE 6.2: Cranial nerve nuclei: Afferent column (NTS: Nucleus tractus solitarious)

	GVA	*SVA*	*GSA*	*SSA*
Functions	Visceral sensation	Taste sensation	Proprioception Tactile sensation from head	Auditory and vestibular impulses
Midbrain	—	—	Mesencephalic nucleus of Vth nerve	—
Pons	NTS	NTS (for facial nerve)	Main sensory nucleus of Vth nerve	Vestibular and cochlear nuclei
Medulla oblongata	NTS	NTS (for IXth, Xth nerves)	Spinal nucleus of Vth nerve	—

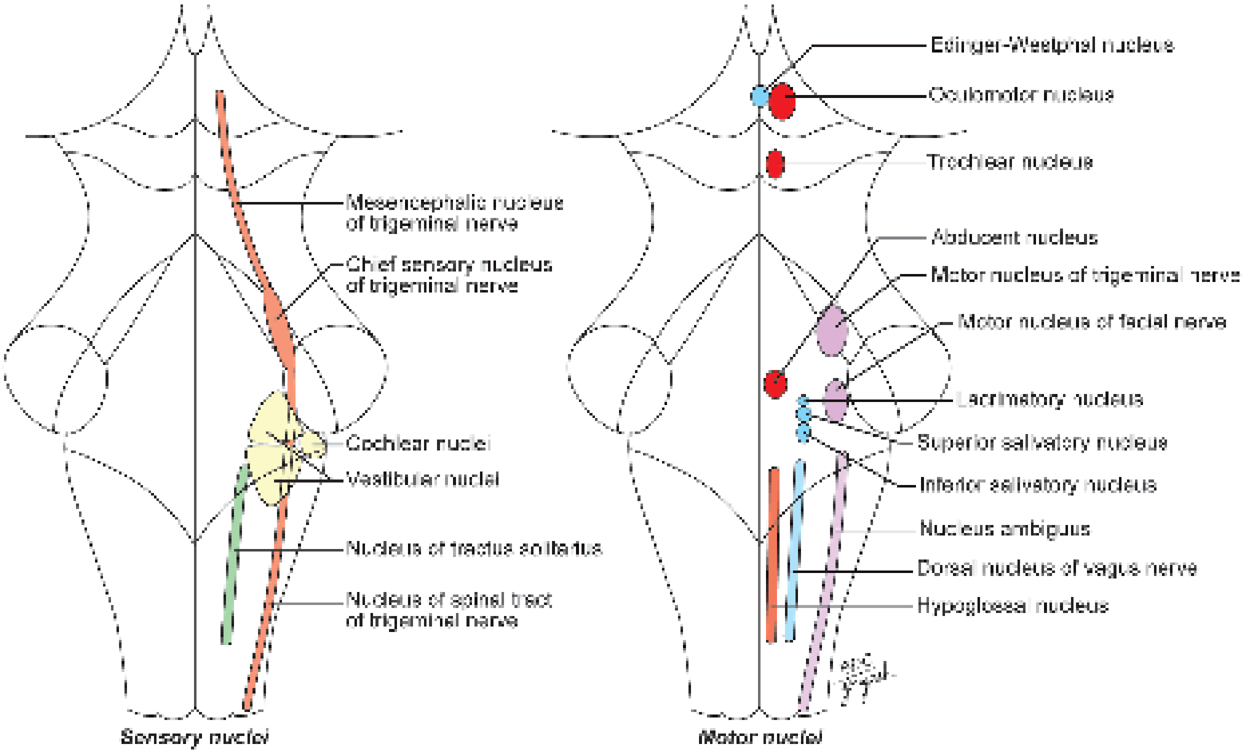

Mesencephalic nucleus of trigeminal nerve
Chief sensory nucleus of trigeminal nerve
Cochlear nuclei
Vestibular nuclei
Nucleus of tractus solitarius
Nucleus of spinal tract of trigeminal nerve
Sensory nuclei
Edinger-Westphal nucleus
Oculomotor nucleus
Trochlear nucleus
Abducent nucleus
Motor nucleus of trigeminal nerve
Motor nucleus of facial nerve
Lacrimatory nucleus
Superior salivatory nucleus
Inferior salivatory nucleus
Nucleus ambiguus
Dorsal nucleus of vagus nerve
Hypoglossal nucleus
Motor nuclei

Fig. 6.3: Surface projection of cranial nerve nuclei on the dorsal aspect of the brainstem

4. ***Hypoglossal nucleus*** lies in the medulla. It is elongated and extends into both the open and closed parts of the medulla. It supplies seven out of eight muscles of the tongue through the hypoglossal nerve.

Special Visceral Efferent/Branchial Efferent Nuclei (Fig. 6.3)

These nuclei supply striated muscles derived from the branchial arches.

1. ***Motor nucleus of the trigeminal nerve*** lies in the upper part of the pons. It supplies the muscles of mastication through the mandibular nerve.
2. ***Nucleus of the facial nerve*** lies in the lower part of the pons. It supplies the various muscles innervated by the facial nerve.
3. ***Nucleus ambiguus*** lies in the medulla. It forms an elongated column lying in both the open and closed parts of the medulla. It supplies:
   a. Stylopharyngeus muscle through the glossopharyngeal nerve; and
   b. Muscles of the soft palate, the pharynx and the larynx through the vagus nerve and the cranial part of the accessory nerve.

General Visceral Efferent Nuclei (Fig. 6.3)

These nuclei give origin to preganglionic neurons that relay in a peripheral autonomic ganglion. Postganglionic fibres arising in the ganglion supply smooth muscles or glands.

1. ***Edinger-Westphal nucleus*** lies in the midbrain in close relation to the oculomotor nucleus. Its fibres pass through the oculomotor nerve to the ciliary ganglion to supply the sphincter pupillae and the ciliaris muscles.
2. ***Lacrimatory nucleus*** lies near the salivatory nuclei (in the lower pons). It gives off fibres that pass through the facial nerve and its branch, the greater petrosal nerve to relay in the pterygopalatine ganglion and supply the lacrimal, nasal, palatal and pharyngeal glands.
3. ***Superior salivatory nucleus*** lies in the lower part of the pons. It sends fibres through the facial nerve and its chorda tympani branch to the submandibular ganglion for supply of the submandibular, sublingual salivary glands and glands in the oral cavity.
4. ***Inferior salivatory nucleus*** lies in the lower part of the pons just below the superior nucleus. It sends fibres through the glossopharyngeal nerve to the otic ganglion for supply of the parotid gland.
5. ***Dorsal nucleus of the vagus*** is a long column extending into the open and closed parts of the medulla. It gives off fibres that pass through the vagus nerve to be distributed to thoracic and abdominal viscera (the ganglia concerned are present in the walls of the viscera supplied).

General Visceral Afferent Nucleus and Special Visceral Afferent Nucleus (Fig. 6.3)

The only nucleus in this category is the ***nucleus of solitary tract*** or tractus solitarius. It lies in the medulla and extends into both its closed and open parts.

Its lower part receives *general visceral sensations* as follows:

a. Through the glossopharyngeal nerve from the tonsil, pharynx, posterior part of the tongue, carotid body and carotid sinus.

b. Through the vagus nerve from the pharynx, larynx, trachea, oesophagus and other thoracic and abdominal viscera.

Its upper part also receives *sensations of taste* (special visceral afferent) as follows:

a. From the anterior two-thirds of the tongue, and the palate except circumvallate papillae through the facial (VII) nerve in its superior part.
b. From the posterior one-third of the tongue through the glossopharyngeal nerve (IX) including the circumvallate papillae in its middle part.
c. From the posteriormost part of the tongue and from the epiglottis through the vagus (X) nerve in its inferior part.

General Somatic Afferent Nuclei (Fig. 6.3)

These are all related to the trigeminal nerve.

1. *Main or superior sensory nucleus of the trigeminal nerve* lies in the upper part of the pons.
2. ***Spinal nucleus of the trigeminal nerve*** descends from the main nucleus into the medulla. It reaches the upper two segments of the spinal cord.
   Its parts are:
   a. Pars caudalis which receives impulses of pain, temperature from forehead
   b. Pars interpolaris, which receives impulses from cheek
   c. Pars oralis, which receives impulses from around mouth.
3. ***Mesencephalic nucleus of the trigeminal nerve*** extends upwards from the main sensory nucleus into the midbrain. It is the only example of primary sensory neuron whose cell bodies are within CNS.
   These nuclei receive the following fibres:
   a. Exteroceptive sensations (touch, pain, temperature) from the skin of the face, through the trigeminal nerve; and from a part of the skin of the auricle through the vagus (auricular branch) and through the facial nerve.
   b. Proprioceptive sensations from muscles of mastication reach the mesencephalic nucleus through the trigeminal nerve. The nucleus is also believed to receive proprioceptive fibres from the ocular, facial and lingual muscles, teeth and temporomandibular joint.

Special Somatic Afferent Nuclei (Fig. 6.3)

1. ***Cochlear nuclei*** (dorsal and ventral) that receive impulses of hearing through the cochlear nerve.
2. ***Vestibular nuclei*** (superior, spinal, medial and lateral) that receive fibres from the semicircular canals, the utricle and the saccule through the vestibular nerve.

Note:

Muscles of facial expression of lower quarter of the face are supplied only from contralateral motor cortex.

The muscles of upper face are supplied both from ipsilateral and contralateral motor cortices.

Cranial part of nucleus ambiguus gives fibres to IX, X and cranial root of XI nerve. The caudal part of this nucleus gives fibres to spinal root of XI nerve.

The genioglossus muscle of the tongue receives fibres from contralateral motor cortex only. Rest of the muscles of the tongue receive fibres from both ipsilateral and contralateral motor cortices.

Competency:

AN63.3 Describe the olfactory, visual, auditory and gustatory pathways.

FIRST CRANIAL NERVE

OLFACTORY (SMELL) PATHWAY

It belongs to special visceral afferent column. Olfactory sensation is carried by olfactory system which consists of the following components:

1. Olfactory epithelium and olfactory nerves
2. Olfactory bulb, tract and striae
3. Olfactory areas of cerebrum.

Olfactory Epithelium and Olfactory Nerves

The ***olfactory epithelium*** lines the upper one-third of nasal cavity. It consists of three types of cells (Plate 6.1):

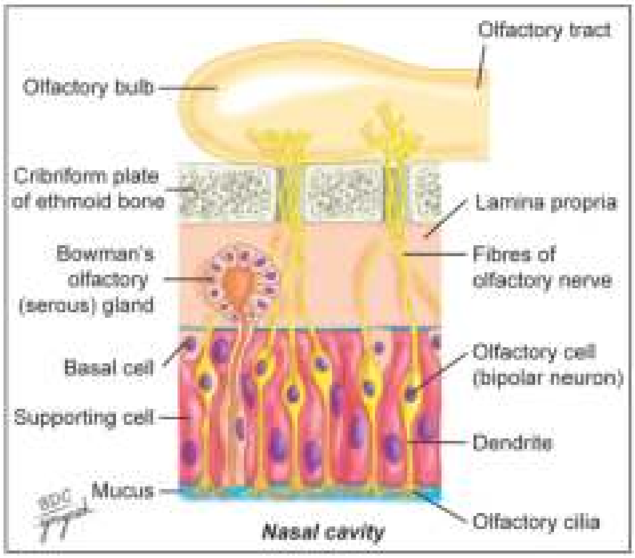
1. *Olfactory receptor cells* (16–20 million in man): These are modified bipolar neurons that receive smell sensation. These cells serve both as receptors as well as the first order neurons in the olfactory pathway.
2. *Supporting cells*.
3. *Basal cells* that can generate the olfactory receptor cells (neurons).

Axons of receptor cells are nonmyelinated. They form about 20 bundles of ***olfactory nerves***. These nerves pass through the cribriform plate of ethmoid to enter the anterior cranial fossa. They terminate in the olfactory bulb.

Olfactory Bulb, Tract, and Striae (Fig. 6.4)

1. ***Olfactory bulb*** is a small oval mass of grey matter situated above the cribriform plate of ethmoid. It has outer *cortical zone* with *olfactory glomeruli* and inner *medullary zones* of nerve fibres.
2. ***Olfactory glomeruli*** consist of mitral cells, tufted cells, stellate cells, periglomerular cells, and axons of olfactory receptor cells.
3. ***Olfactory tract*****:** The olfactory bulb continues posteriorly as olfactory tract. The posterior end of olfactory tract forms a flat *olfactory trigone*.
4. ***Olfactory striae*****:** The olfactory tract divides into medial, intermediate, and lateral olfactory striae.
5. ***Anterior olfactory nucleus*** is a group of neurons situated at the junction of olfactory bulb and tract.
6. ***Medial olfactory stria*** continues in paraterminal gyrus which lies in front of lamina terminalis.
7. ***Lateral olfactory stria*** runs laterally and continues into *limen insulae*. It turns medially to form gyrus semilunaris (periamygdaloid area).
8. ***Intermediate olfactory stria*** is occasionally present. It ends as olfactory tubercle in the anterior perforated substance.
9. ***Medial*** **and** ***lateral olfactory gyri*** are thin layers of grey matter that cover the medial and lateral olfactory stria.

Plate 6.1: Olfactory mucosa


Olfactory tract
Olfactory bulb
Cribriform plate of ethmoid bone
Lamina propria
Bowman's olfactory (serous) gland
Fibres of olfactory nerve
Basal cell
Olfactory cell (bipolar neuron)
Supporting cell
Dendrite
Mucus
Nasal cavity
Olfactory cilia

Olfactory Areas

1. ***Primary olfactory area*** is responsible for reception and perception of smell. It includes lateral olfactory gyrus, gyrus ambiens, gyrus semilunaris, limen insulae, uncus and dorsomedial part of amygdaloid body.
2. ***Secondary olfactory area (entorhinal area)*** performs the olfactory association. It includes the anterior part of parahippocampal gyrus. It is called area 28. Fibres arising in the primary olfactory cortex go to the secondary olfactory cortex and tertiary olfactory cortex in posterior part of orbitofrontal cortex.

Note:

Smell is perceived in both the primary and secondary olfactory areas.

Some impulses from uncus travel via medial forebrain bundle and reticular formation to dorsal nucleus of vagus and salivatory nuclei in medulla oblongata, where these may increase or decrease gastric secretion according to type of smell.

Olfactory afferent pathway comprises only two neurons. The fibres reach the cerebral cortex without synapsing in any of the thalamic nuclei.

CLINICAL NEUROANATOMY

- ***Anosmia:*** Loss of olfactory fibres with ageing. Allergic rhinitis causes temporary olfactory impairment.
- Sense of smell is tested separately in each nostril.
- *Head injury:* Olfactory bulbs may be torn away from olfactory nerves as these pass through fractured cribriform plate of ethmoid leading to anosmia. Such a fracture may also cause CSF rhinorrhoea, i.e. CSF leakage through the nose.
- Abscess of frontal lobe of brain or meningioma in the anterior cranial fossa may press on the olfactory bulb or olfactory tract resulting in anosmia.

SECOND CRANIAL NERVE

The optic nerve is the 2nd cranial nerve. It is purely sensory and a nerve of sight or vision. It emerges from the eyeball, about 3 to 4 mm nasal to its posterior pole. It runs backwards and medially to enter the optic canal. Finally, it enters the middle cranial fossa and unite with opposite nerve to form optic chiasma.

Length: The optic nerve is 4 cm long.

Note: Human vision is binocular, though one sees with both the eyes, the inverted images formed are seen as one and straight only. Human vision is stereoscopic, i.e. one sees height, width and thickness of the object. Human vision is coloured, one sees different colours put up by nature.

Parts

It has the following courses:

1. Intraorbital: 25 mm
2. Intracanalicular: 5 mm
3. Intracranial: 10 mm.

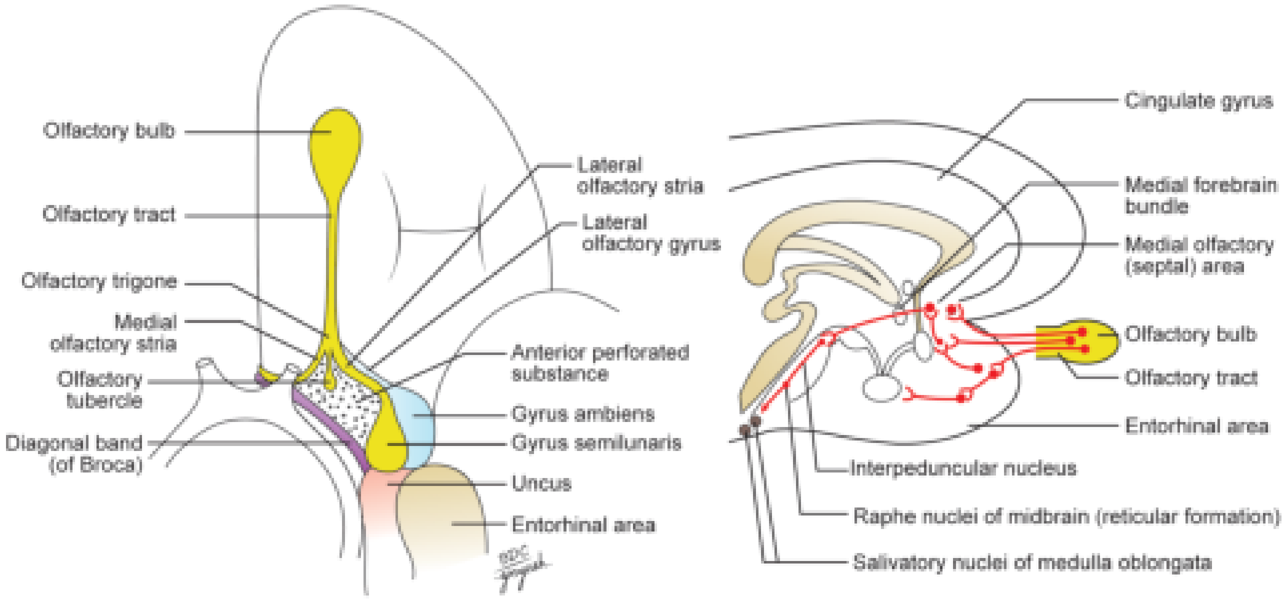

Olfactory bulb
Olfactory tract
Olfactory trigone
Medial olfactory stria
Olfactory tubercle
Diagonal band (of Broca)
Lateral olfactory stria
Lateral olfactory gyrus
Anterior perforated substance
Gyrus ambiens
Gyrus semilunaris
Uncus
Entorhinal area
Cingulate gyrus
Medial forebrain bundle
Medial olfactory (septal) area
Olfactory bulb
Olfactory tract
Entorhinal area
Interpeduncular nucleus
Raphe nuclei of midbrain (reticular formation)
Salivatory nuclei of medulla oblongata

Fig. 6.4: Components of olfactory pathway (inferior view of brain)

Peculiarities of Optic Nerve

1. The optic nerve is not a true cranial nerve.
2. It is an extension of diencephalon during embryonic life.
3. It consists of 2nd order sensory neurons.
4. It consists of fibres myelinated by oligodendrocytes (instead of Schwann cells).
5. It is surrounded by meninges.
6. Its fibre cannot regenerate if damaged.

Functional Component

Special somatic afferent fibres: Optic nerve carries sense of sight from eye.

Course and Relations

Beginning: The ganglion cells of retina give rise to the fibres of optic nerve. These fibres converge toward the optic disc at the posterior pole of the eyeball. These fibres pierce the retina, choroid and sclera and emerge from the eyeball as optic nerve.

Course: The optic nerve pass posteromedially in the orbit and enters the middle cranial fossa through optic canal.

Termination: Both the optic nerves join to form optic chiasma in the middle cranial fossa.

VISUAL PATHWAY

Field of Vision

It includes four fields—upper temporal, lower temporal, upper nasal and lower nasal. Nasal fields are smaller than the temporal fields. Larger right temporal and smaller right nasal fields of vision fuse to form right part of ***binocular field***. Left halves of field of vision, i.e. larger temporal half and smaller nasal half of left field of vision form left half of binocular field (Figs 6.5a to d).

Most importantly, there is a macular vision which is the most acute or sharp and coloured vision.

Retina

The retina is also divided into temporal and nasal parts and each is further subdivided into upper and lower parts. Temporal field is seen by nasal hemiretina and vice versa.

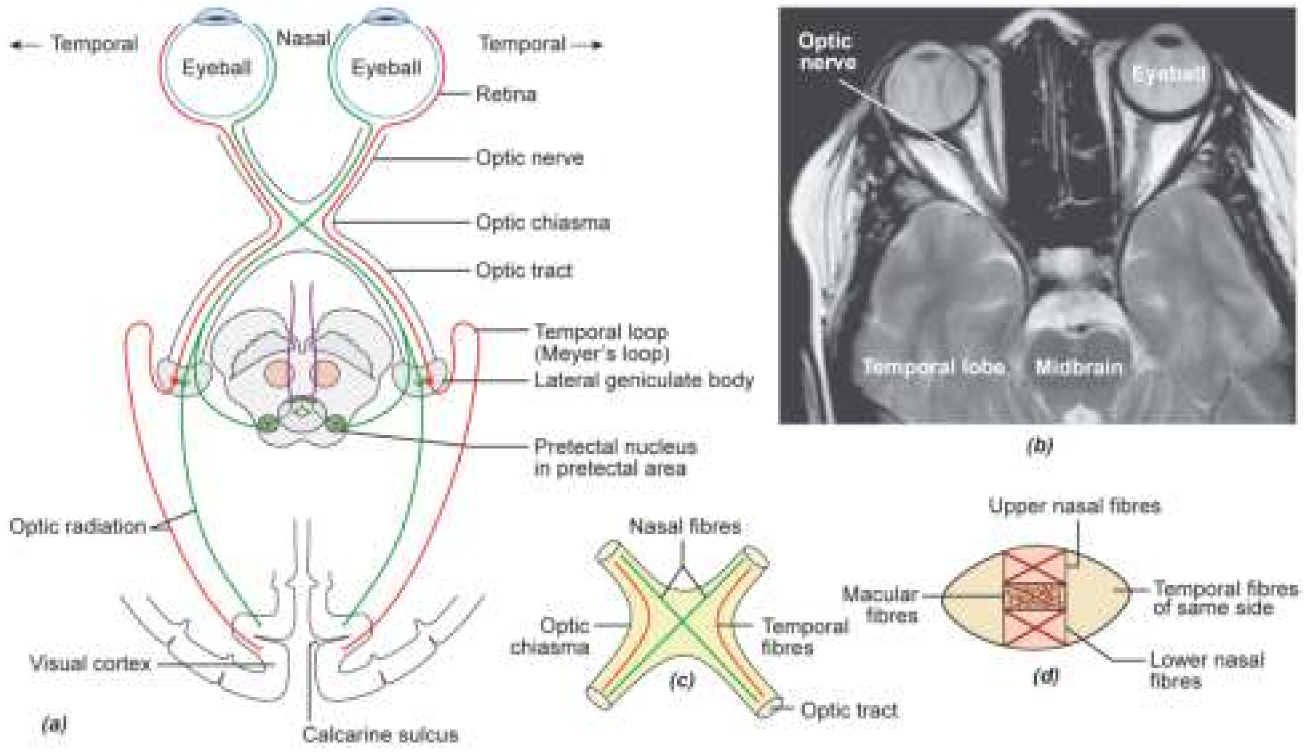
The 1st order neurons are represented by the ***bipolar cells of retina***. They receive impulses from the rods and cones present in the retina.

Optic Nerve

Optic nerve is made up of axons of ***ganglion cells of the retina*** which form the 2nd order neurons. In a strict sense, the optic nerve is not a peripheral nerve because its fibres have no neurilemmal sheaths. It is a tract. Its fibres have no power of regeneration.

Optic Chiasma

In the chiasma, the nasal fibres (i.e. fibres of the optic nerve arising in the nasal, or medial half of the retina) including those from the nasal half of the macula, cross the midline and enter the opposite optic tract. The temporal (lateral) fibres pass through the chiasma to enter the optic tract of the same side.


← Temporal
Nasal
Temporal →
Eyeball
Eyeball
Retina
Optic nerve
Optic chiasma
Optic tract
Temporal loop (Meyer's loop)
Lateral geniculate body
Pretectal nucleus in pretectal area
Optic radiation
Visual cortex
Calcarine sulcus
(a)
Optic nerve
Eyeball
Temporal lobe
Midbrain
(b)
Nasal fibres
Optic chiasma
Temporal fibres
Optic tract
(c)
Upper nasal fibres
Macular fibres
Temporal fibres of same side
Lower nasal fibres
(d)

Figs 6.5a to d: (a) Visual pathways showing binocular vision, (b) MRI showing optic nerve, (c) superior view of fibres in optic chiasma, and (d) sectional view of fibres in optic chiasma

Optic Tract

Each optic tract winds round the cerebral peduncle of the midbrain. Near the lateral geniculate body, it divides into ***lateral and medial roots***. The lateral root is thick and terminates in the lateral geniculate body. A few of its fibres pass to the superior colliculus, the pretectal nucleus and the hypothalamus. The medial root is believed to contain the supraoptic commissural fibres.

Each optic tract contains temporal fibres of retina of the same side and nasal fibres of the opposite side.

Lateral Geniculate Body

Lateral geniculate body receives the lateral root of the optic tract. Medially, it is connected to the superior colliculus, and laterally, it gives rise to the optic radiation.

The cells in this body are arranged in six layers which form the third order neurons.

Layers 2, 3, 5 receive ipsilateral fibres, and layers 1, 4, 6 receive contralateral fibres.

Optic Radiation (Geniculocalcarine Tract)

Optic radiation begins from the lateral geniculate body, passes through the retrolentiform part of internal capsule, and ends in the visual cortex.

Visual Cortex

The optic radiation terminates in the striate area where the colour, size, shape, motion, illumination and transparency are appreciated separately. Objects are identified by integration of these perceptions with past experience stored in the parastriate and peristriate areas 18 and 19.

The area of the visual cortex that receives impulses from the macula is relatively much larger than the part related to the rest of the retina.

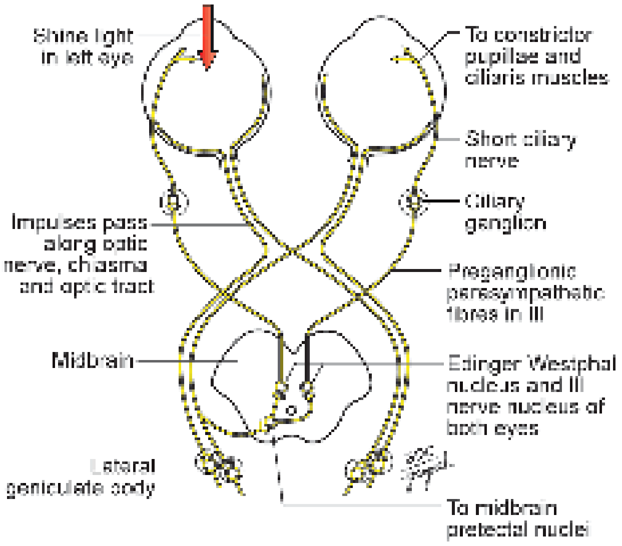
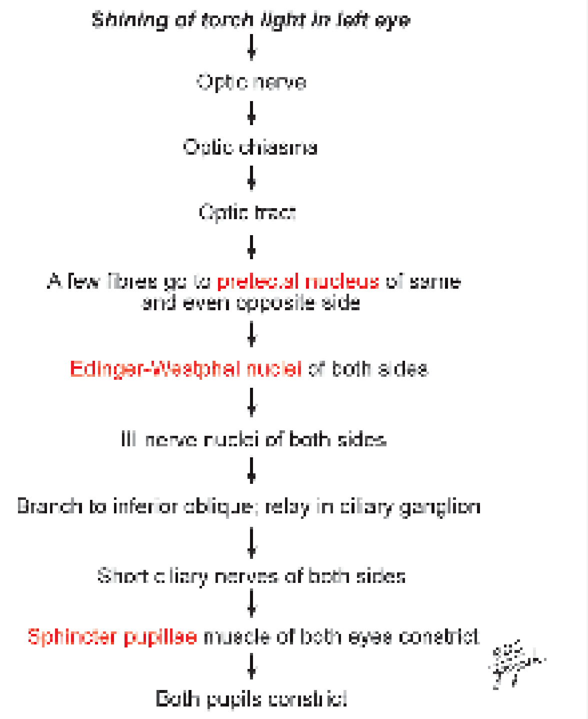

Shine light in left eye
To constrictor pupillae and ciliaris muscles
Short ciliary nerve
Ciliary ganglion
Impulses pass along optic nerve, chiasma and optic tract
Preganglionic parasympathetic fibres in III
Midbrain
Edinger Westphal nucleus and III nerve nucleus of both eyes
Lateral geniculate body
To midbrain pretectal nuclei

Fig. 6.6: Pupillary light and consensual light reflex

Flowchart 6.1: Pupillary light reflex


Shining of torch light in left eye
Optic nerve
Optic chiasma
Optic tract
A few fibres go to pretectal nucleus of same and even opposite side
Edinger-Westphal nuclei of both sides
III nerve nuclei of both sides
Branch to inferior oblique; relay in ciliary ganglion
Short ciliary nerves of both sides
Sphincter pupillae muscle of both eyes constrict
Both pupils constrict

CLINICAL NEUROANATOMY

- ***Reflexes:*** These are:
  1. Pupillary light and consensual light reflex (Fig. 6.6 and Flowchart 6.1)
  2. Dilation of pupil (Flowchart 6.2)
  3. Accommodation reflex (Fig. 6.7 and Flowchart 6.3)
  4. Corneal/conjunctival reflex (Fig. 6.8 and Flowchart 6.4)
  5. Visual body reflex (Fig. 6.9 and Flowchart 6.5).
- Lesion in retina leads to scotoma, that is certain points may become blind spots.
- Loss of vision in one-half (left or right) of visual field is called ***hemianopia***. If the defect is in same halves of both eyes, it is called ***homonymous hemianopia***. If defect is in different halves, it is called ***heteronymous hemianopia***.
- Optic nerve damage results in complete blindness of that eye (Fig. 6.10).
- Optic chiasma lesion, if central will lead to ***bitemporal hemianopia***, but if peripheral on both sides will lead to ***binasal hemianopia*** (Fig. 6.10).
- Complete destruction of optic tract, lateral geniculate body, optic radiation or visual cortex of one side results in loss of the opposite half of field of vision.
- A lesion on the right optic tract leads to ***left homonymous hemianopia*** (left half of field of vision).
- ***Papilloedema:*** Results due to increased intracranial pressure. It leads to swelling of optic disc due to blockage of tributaries of the retinal veins.
- ***Optic neuritis:*** Lesion of optic nerve that results in decrease of visual acuity. Optic disc appears pale

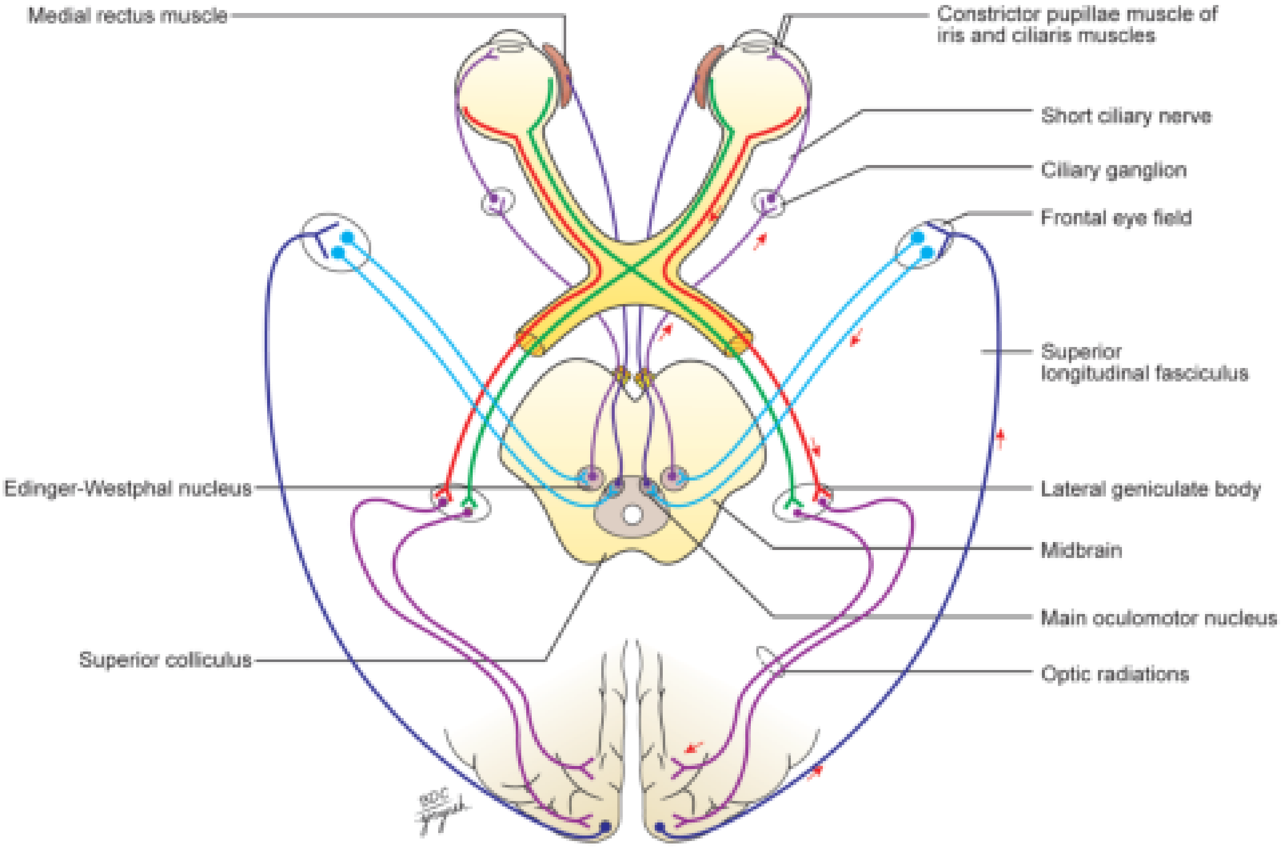
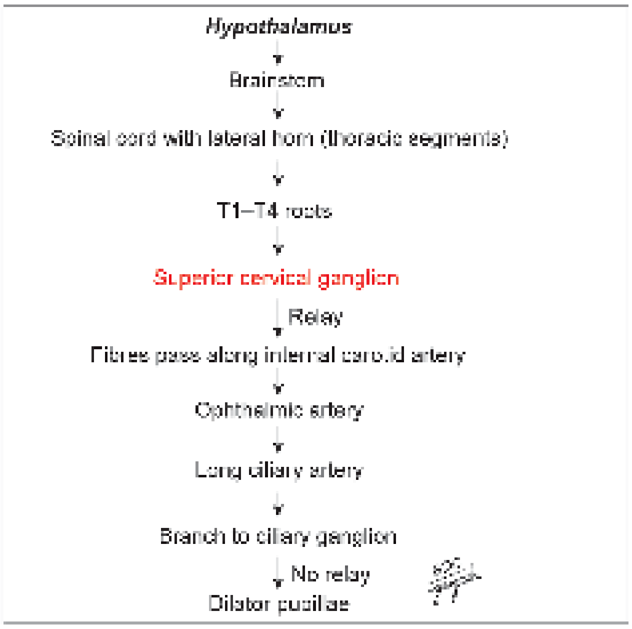

Medial rectus muscle
Constrictor pupillae muscle of iris and ciliaris muscles
Short ciliary nerve
Ciliary ganglion
Frontal eye field
Superior longitudinal fasciculus
Edinger-Westphal nucleus
Lateral geniculate body
Midbrain
Main oculomotor nucleus
Superior colliculus
Optic radiations

Fig. 6.7: Accommodation reflex

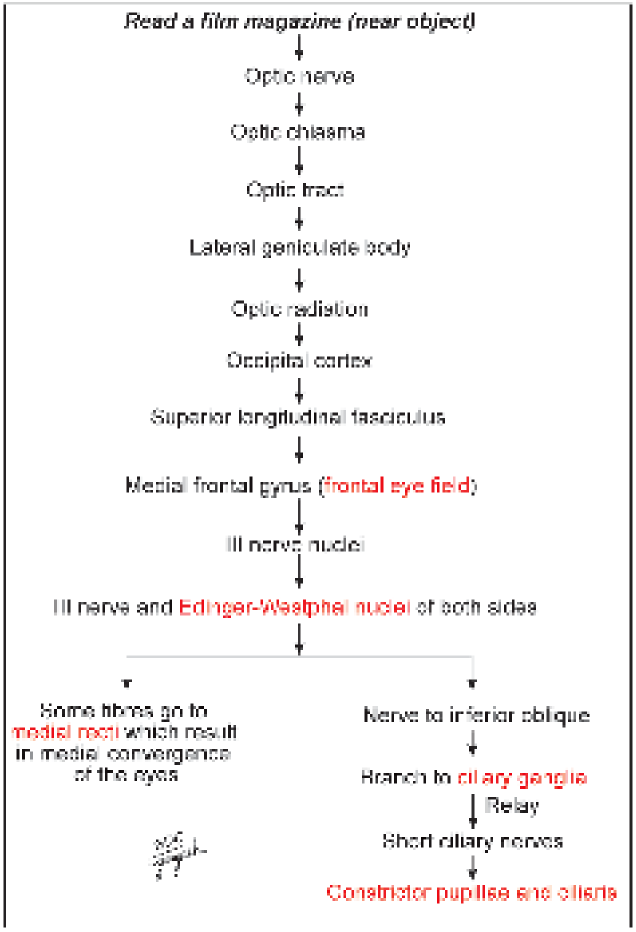
Flowchart 6.2: Dilation of pupil


Hypothalamus
Brainstem
Spinal cord with lateral horn (thoracic segments)
T1–T4 roots
Superior cervical ganglion
Relay
Fibres pass along internal carotid artery
Ophthalmic artery
Long ciliary artery
Branch to ciliary ganglion
No relay
Dilator pupillae

and smaller. Methyl alcohol is a usual toxic chemical leading to blindness.

- ***Argyll Robertson pupil:*** In this condition, the accommodation reflex is present but the light reflex is absent. The pretectal area is affected.
- ***Foster Kennedy syndrome*** – tumour at the base of frontal lobe resulting in compression of nerve.

Flowchart 6.3: Accommodation reflex


Read a film magazine (near object)
Optic nerve
Optic chiasma
Optic tract
Lateral geniculate body
Optic radiation
Occipital cortex
Superior longitudinal fasciculus
Medial frontal gyrus (frontal eye field)
III nerve nuclei
III nerve and Edinger-Westphal nuclei of both sides
Some fibres go to medial recti which result in medial convergence of the eyes
Nerve to inferior oblique
Branch to ciliary ganglia
Relay
Short ciliary nerves
Constrictor pupillae and ciliaris

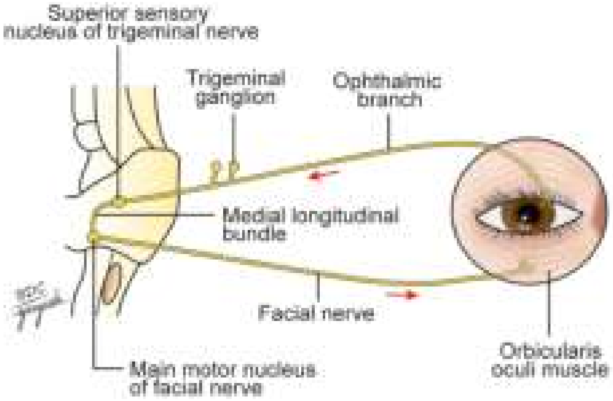

Superior sensory nucleus of trigeminal nerve
Trigeminal ganglion
Ophthalmic branch
Medial longitudinal bundle
Facial nerve
Orbicularis oculi muscle
Main motor nucleus of facial nerve

Fig. 6.8: Corneal/conjunctival reflex

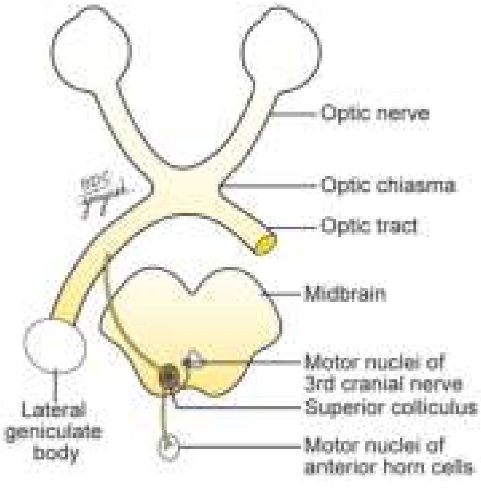

Optic nerve
Optic chiasma
Optic tract
Midbrain
Motor nuclei of 3rd cranial nerve
Superior colliculus
Motor nuclei of anterior horn cells
Lateral geniculate body

Fig. 6.9: Visual body reflex

Flowchart 6.4: Corneal/conjunctival reflex

Touching of cornea or conjunctiva
↓
Ophthalmic nerve
↓
Superior sensory nucleus of V
↓
Medial longitudinal bundle
↓
Motor nucleus of VII
↓
Orbicularis oculi constricts

Flowchart 6.5: Visual body reflex

Retina
↓
Optic nerve
↓
Optic chiasma
↓
Optic tract
↓
Superior colliculus
↓

Motor nuclei of cranial nerves for movements of head and neck

Anterior horn cells of spinal cord for movements of body

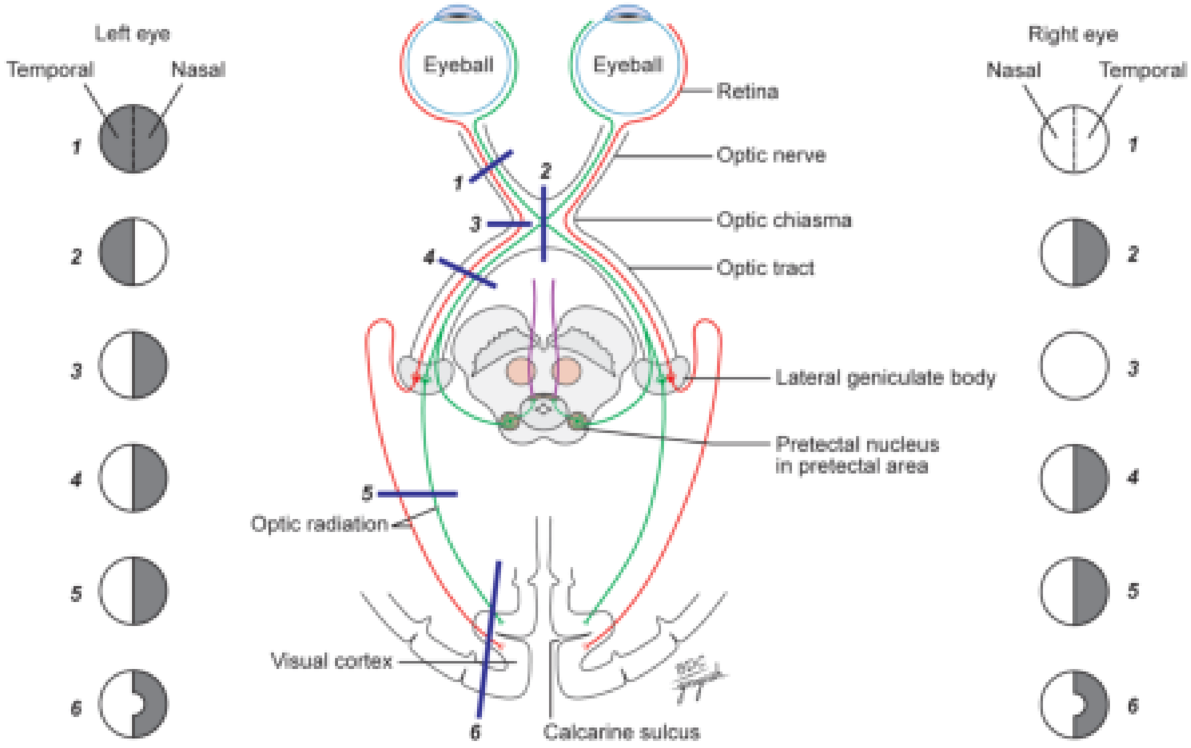

Left eye
Temporal
Nasal
Right eye
Nasal
Temporal
Eyeball
Eyeball
Retina
Optic nerve
Optic chiasma
Optic tract
Lateral geniculate body
Pretectal nucleus in pretectal area
Optic radiation
Visual cortex
Calcarine sulcus
1
2
3
4
5
6

Fig. 6.10: Field defects associated with lesion of visual pathway: (1) Blindness of left eye; (2) Bitemporal hemianopia; (3) Left nasal hemianopia; (4) Right homonymous hemianopia with macular involvement; (5) Right homonymous hemianopia; (6) Right homonymous hemianopia with macular sparing

THIRD CRANIAL NERVE (OCULOMOTOR NERVE)

Oculomotor nerve is the 3rd cranial nerve. It is distributed to the extraocular as well as the intraocular muscles. Since it is a somatic motor nerve, it is in series with the IV, VI and XII cranial nerves, and also with the ventral root of spinal nerves (Flowchart 6.6).

Functional Components

1. *General somatic efferent fibres (GSE)* arise from the *motor nucleus of oculomotor nerve* – for the extraocular muscles of eyeball (Fig. 6.11).
2. *General visceral efferent (GVE)* or *parasympathetic fibres* arise from the *Edinger-Westphal nucleus*. They supply sphincter pupillae and ciliary muscles – for contraction of pupil and accommodation.
3. *General somatic afferent column (GSA)* carries proprioceptive fibres from the extraocular muscles to mesencephalic nucleus of V.

Nucleus

The ***oculomotor nucleus*** is situated in the ventromedial part of central grey matter of midbrain at the level of superior colliculus (Flowchart 6.7). Ventrolaterally, it is closely related to the medial longitudinal bundle.

The nucleus is connected:

a. To the *pyramidal tracts of both sides* which form the supranuclear pathway of the nerve.
b. To the *pretectal nuclei* of both sides for the light reflex.
c. To the *4th, 6th and 8th nerve nuclei* by *medial longitudinal bundle* for coordination of the eye movements.
d. To the *tectobulbar tract* for visuoprotective reflexes.
e. To mesencephalic nucleus of trigeminal nerve.

Origin of Nerve

The oculomotor nerve arises as a single trunk which emerges through a sulcus on the medial side of crus cerebri (midbrain).

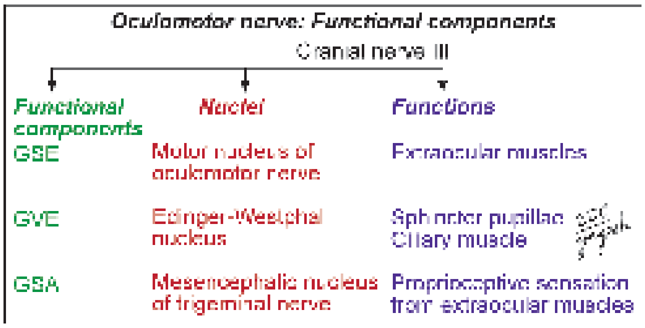
Course and Distribution

The course of the oculomotor nerve is divided into three segments (Figs 6.12 and 6.13):

1. Intraneuronal course
2. Intracranial course
3. Orbital course.

Intraneuronal course: The fibres of oculomotor nerve arise from the nucleus and traverse through tegmentum, red nucleus, and substantia nigra (in midbrain).

Flowchart 6.6: Oculomotor nerve: functional components



Oculomotor nerve: Functional components

Cranial nerve III

Functional components	*Nuclei*	*Functions*
GSE	Motor nucleus of oculomotor nerve	Extraocular muscles
GVE	Edinger-Westphal nucleus	Sphincter pupillae Ciliary muscle
GSA	Mesencephalic nucleus of trigeminal nerve	Proprioceptive sensation from extraocular muscles

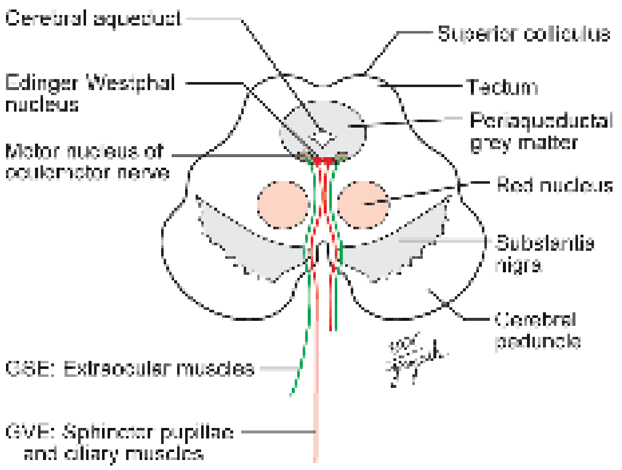
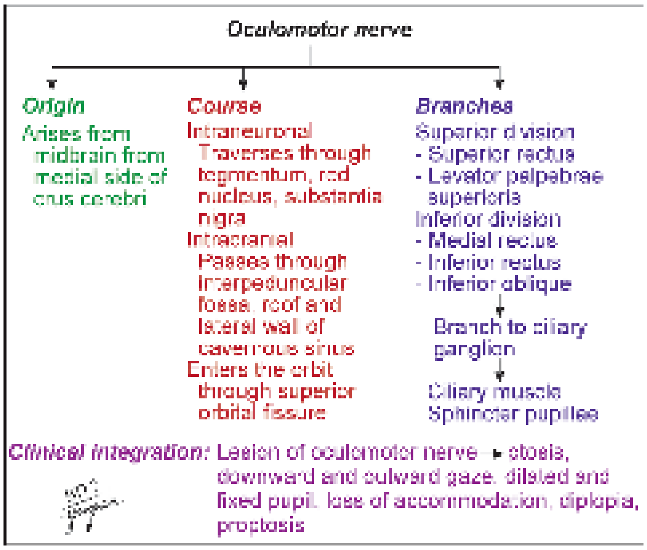


Fig. 6.11: Third cranial nerve and its nucleus

Flowchart 6.7: Oculomotor nerve



Oculomotor nerve

Origin	*Course*	*Branches*
Arises from midbrain from medial side of crus cerebri	Intraneuronal Traverses through tegmentum, red nucleus, substantia nigra Intracranial Passes through interpeduncular fossa, roof and lateral wall of cavernous sinus Enters the orbit through superior orbital fissure	Superior division - Superior rectus - Levator palpebrae superioris Inferior division - Medial rectus - Inferior rectus - Inferior oblique Branch to ciliary ganglion Ciliary muscle Sphincter pupillae

Clinical integration: Lesion of oculomotor nerve → ptosis, downward and outward gaze, dilated and fixed pupil, loss of accommodation, diplopia, proptosis

Intracranial course: The nerve arises from the oculomotor sulcus on the medial aspect of the cerebral peduncle of the *midbrain*. It traverses forwards in the *interpeduncular fossa*, in between the posterior cerebral and superior cerebellar arteries. It *enters the roof of cavernous sinus* and runs in the lateral wall of sinus, superior to the trochlear nerve. In the anterior part of cavernous sinus, the oculomotor nerve divides into the smaller superior and larger inferior divisions which enter the orbit through the *superior orbital fissure* within the tendinous ring.

In the orbit

Superior division: It passes forwards and upward lateral to the optic nerve. It supplies superior rectus and pierces this muscle to reach and supply the *levator palpebrae superioris* muscle.

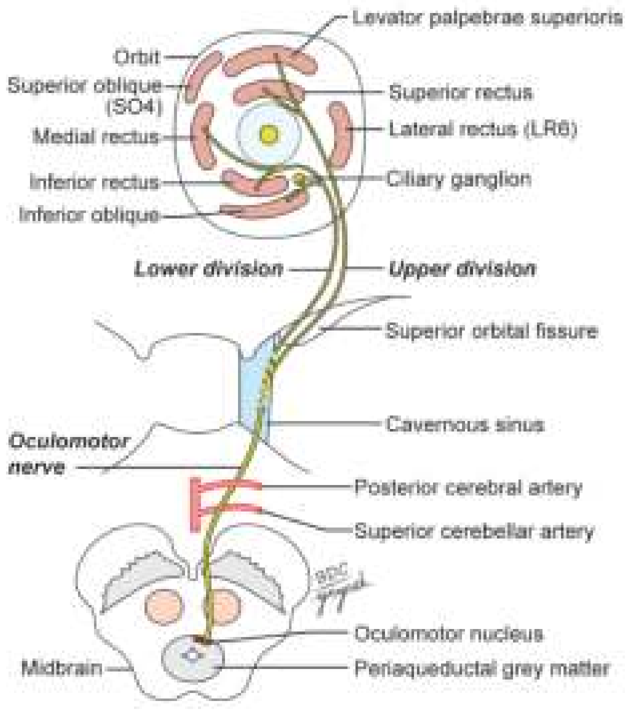

Levator palpebrae superioris
Orbit
Superior oblique (SO4)
Medial rectus
Inferior rectus
Inferior oblique
Superior rectus
Lateral rectus (LR6)
Ciliary ganglion
Lower division
Upper division
Superior orbital fissure
Cavernous sinus
Oculomotor nerve
Posterior cerebral artery
Superior cerebellar artery
Oculomotor nucleus
Midbrain
Periaqueductal grey matter

Fig. 6.12: The origin, course and the distribution of oculomotor nerve

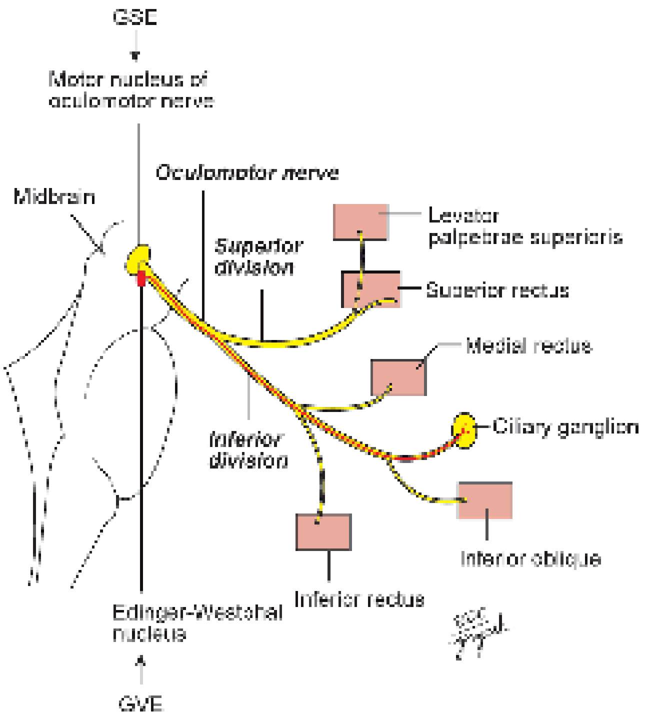

GSE
Motor nucleus of oculomotor nerve
Oculomotor nerve
Midbrain
Superior division
Levator palpebrae superioris
Superior rectus
Medial rectus
Inferior division
Ciliary ganglion
Inferior oblique
Inferior rectus
Edinger-Westphal nucleus
GVE

Fig. 6.13: Oculomotor nerve (schematic representation)

Inferior division: It divides into three branches to supply

1. Medial rectus
2. Inferior rectus
3. Inferior oblique.

The branch to the inferior oblique provides a communicating branch to the *ciliary ganglion*.

Competency:

AN31.5 Explain the anatomical basis of oculomotor, trochlear and abducent nerve palsies along with strabismus.

CLINICAL NEUROANATOMY

- The damage to the oculomotor nerve may be caused by compression by aneurysm of posterior cerebral or posterior communicating arteries or internal carotid artery. Complete or total damage to oculomotor nerve results into (Fig. 6.14):
  1. *Ptosis* or drooping of the of the upper eyelid ← due to paralysis of levator palpebrae superioris.
  2. *Downward and outward gaze* (*previous concept: Lateral strabismus or squint*) ← due to unopposed actions of lateral rectus and superior oblique.
  3. *Dilated and fixed pupil* ← due to paralysis of the sphincter pupillae and ciliary muscles.
  4. *Loss of accommodation* ← due to paralysis of sphincter pupillae and ciliary muscles.
  5. *Diplopia* ← due to paralysis of inferior oblique, inferior rectus, and medial rectus muscles.
  6. *Proptosis* ← due to paralysis of extraocular muscles.
- ***Weber syndrome*** (*superior alternating hemiplegia*): A midbrain lesion causing contralateral hemiplegia and ipsilateral paralysis of the third nerve is known as *Weber's syndrome*.
  1. Oculomotor nerve → lower motor neuron paralysis of extraocular muscles of same side.
  2. Crus cerebri (pyramidal fibres) → upper motor neurons paralysis of opposite side of the body.
- ***Supranuclear paralysis of the 3rd nerve*** causes loss of conjugate movement of the eyes.
- ***Compression of III nerve****:* Compression of III nerve due to extradural haematoma causes dilatation of pupil. Parasympathetic fibres lying superficial get affected first. Pupil dilates on affected side and there is little response to light.
- *Aneurysm of posterior cerebral or superior cerebellar artery:* Aneurysm of any of these two arteries may compress III nerve as it passes between them.

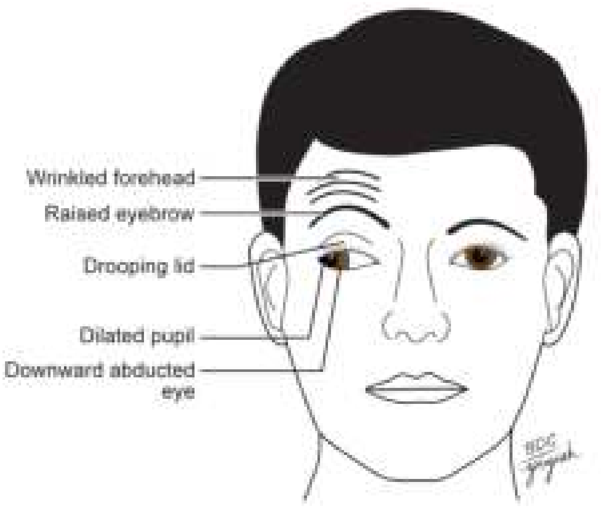

Wrinkled forehead
Raised eyebrow
Drooping lid
Dilated pupil
Downward abducted eye

Fig. 6.14: Paralysis of right oculomotor nerve

FOURTH CRANIAL NERVE (TROCHLEAR NERVE)

Trochlear nerve supplies only the superior oblique muscle of the eyeball (Flowchart 6.8 and Fig. 6.15). It is the only cranial nerve which emerges on the dorsal aspect of the brainstem.

Functional Components

1. *General somatic efferent (GSE) fibres* arise from the *trochlear nucleus* in the midbrain at the level of inferior colliculus and it supplies the superior oblique muscle of the eyeball.
2. *General somatic afferent fibres (GSA)* fibres carry proprioception from the superior oblique muscle to the *mesencephalic nucleus of the trigeminal nerve.*

Peculiarities of Trochlear Nerve

1. It is the thinnest cranial nerve.
2. It supplies only one muscle – superior oblique.
3. It is the only cranial nerve that emerges on the dorsal aspect of the brain.
4. It is only cranial nerve whose fibres decussate in the brainstem before it emerges.
5. Its nucleus receives only the ipsilateral corticonuclear fibres.

Nucleus

The ***trochlear nucleus*** is situated in the ventromedial part of the central grey matter of midbrain at the level of inferior colliculus. Ventrally, it is closely related to the medial longitudinal bundle.

The connections of the nucleus are similar to those of the oculomotor nucleus, except for the pretectal nuclei.

Origin of Nerve

The trochlear nerve emerges on the dorsal aspect of the *midbrain*, one on either side of frenulum veli.

Course and Distribution

The course of the trochlear nerve is divided into the following parts (Fig. 6.16):

1. Intraneural course
2. Intracranial course
3. Orbital course.

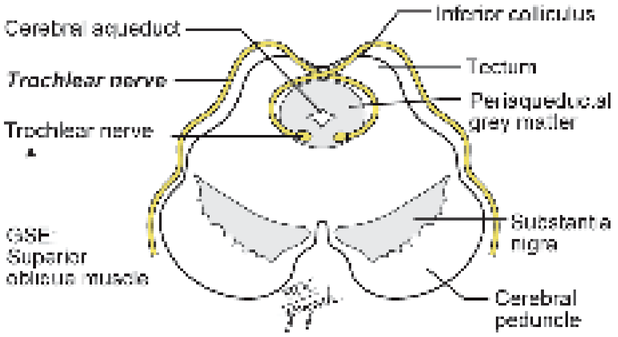

Cerebral aqueduct
Inferior colliculus
Trochlear nerve
Tectum
Periaqueductal grey matter
Trochlear nerve
GSE
Superior oblique muscle
Substantia nigra
Cerebral peduncle

Fig. 6.15: Emerging fibres of trochlear nerves with their nuclei

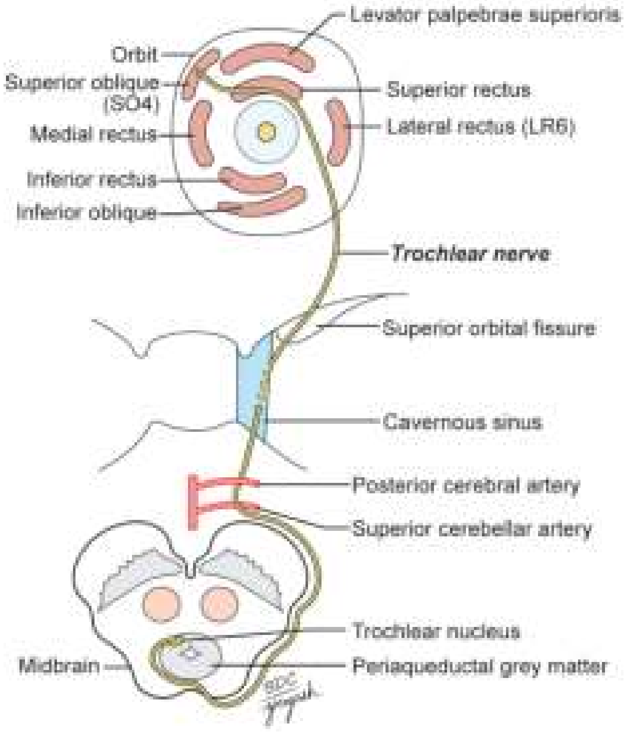
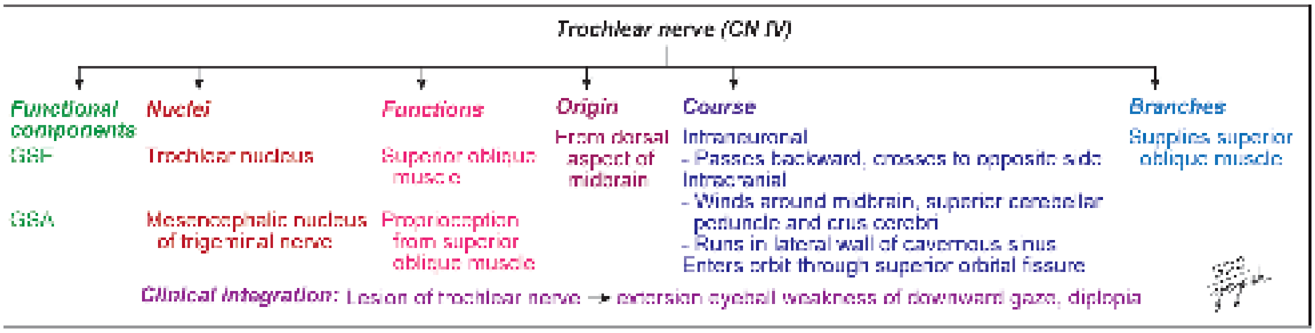

Levator palpebrae superioris
Orbit
Superior oblique (SO4)
Superior rectus
Medial rectus
Lateral rectus (LR6)
Inferior rectus
Inferior oblique
Trochlear nerve
Superior orbital fissure
Cavernous sinus
Posterior cerebral artery
Superior cerebellar artery
Trochlear nucleus
Midbrain
Periaqueductal grey matter

Fig. 6.16: The origin, course and the distribution of the trochlear nerve

Intraneural course: The fibres of trochlear nerve begin from the *trochlear nucleus* which located in the periaqueductal grey matter of the *midbrain* at the level of inferior colliculus. These fibres pass backwards around the grey matter and cross to opposite side behind the periaqueductal grey matter.

Flowchart 6.8: Trochlear nerve (CN IV)


Trochlear nerve (CN IV)
Functional components
GSE
GSA
Nuclei
Trochlear nucleus
Mesencephalic nucleus of trigeminal nerve
Functions
Superior oblique muscle
Proprioception from superior oblique muscle
Origin
From dorsal aspect of midbrain
Course
Intraneuronal
- Passes backward, crosses to opposite side
Intracranial
- Winds around midbrain, superior cerebellar peduncle and crus cerebri
- Runs in lateral wall of cavernous sinus
Enters orbit through superior orbital fissure
Branches
Supplies superior oblique muscle
Clinical integration: Lesion of trochlear nerve → extorsion eyeball weakness of downward gaze, diplopia

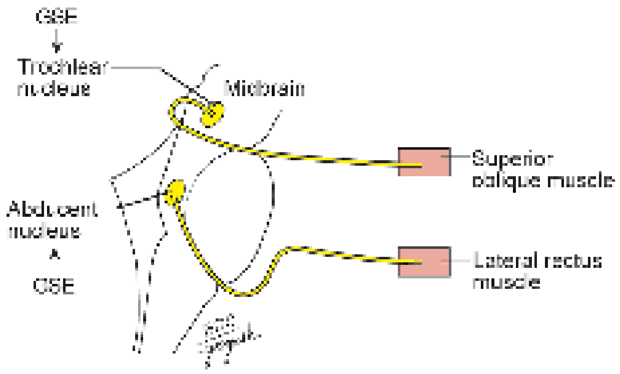

GSE
Trochlear nucleus
Midbrain
Superior oblique muscle
Abducent nucleus
GSE
Lateral rectus muscle

Fig. 6.17: Trochlear and abducent nerve (schematic representation)

Intracranial course: The nerve emerges on the dorsal aspect of the midbrain, one on either side of frenulum veli. Then, it winds around the superior cerebellar peduncle and cerebral peduncle, just above the pons. It passes forwards between the posterior cerebral and superior cerebellar arteries. It pierces the roof of cavernous sinus and runs forwards in its lateral wall between oculomotor and ophthalmic nerves.

Orbital course: Trochlear nerve enters the orbit through the *superior orbital fissure*, superolateral to the tendinous ring. It runs medially and forwards above the levator palpebrae superioris to enter the orbital surface of superior oblique muscle.

Branch

The trochlear nerve supplies only one muscle – *superior oblique muscle* (Fig. 6.17).

CLINICAL NEUROANATOMY

- The trochlear nerve lesion causes paralysis of the superior oblique muscle. It produces two effects as follows:
  1. *Extorsion* of eyeball and weakness of downward gaze
  2. *Diplopia* (double vision) on looking downward.
- Due to these effects, the patient faces difficulty while going downstairs or reading newspaper. To avoid diplopia, the patient tilts the head forwards and to the unaffected side.

SIXTH CRANIAL NERVE (ABDUCENT NERVE)

Abducent nerve supplies the lateral rectus muscle of the eyeball (Figs 6.18, 6.19 and Flowchart 6.9). It has a long intradural course.

Functional Components

1. *General somatic efferent* (*GSE*) fibres arise from *abducent nucleus* in the pons and supply the lateral rectus muscle of the eyeball.
2. *General somatic afferent* (*GSA*) fibres carry proprioception from the lateral rectus muscle to the *mesencephalic nucleus of trigeminal nerve*.

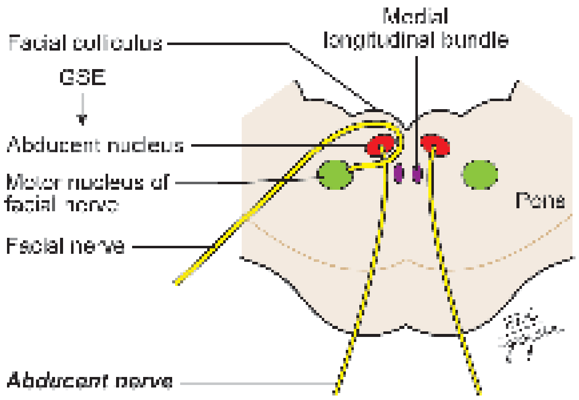

Facial colliculus
Medial longitudinal bundle
GSE
Abducent nucleus
Motor nucleus of facial nerve
Pons
Facial nerve
Abducent nerve

Fig. 6.18: VI nerve with its nucleus. It includes unusual course of VII nerve

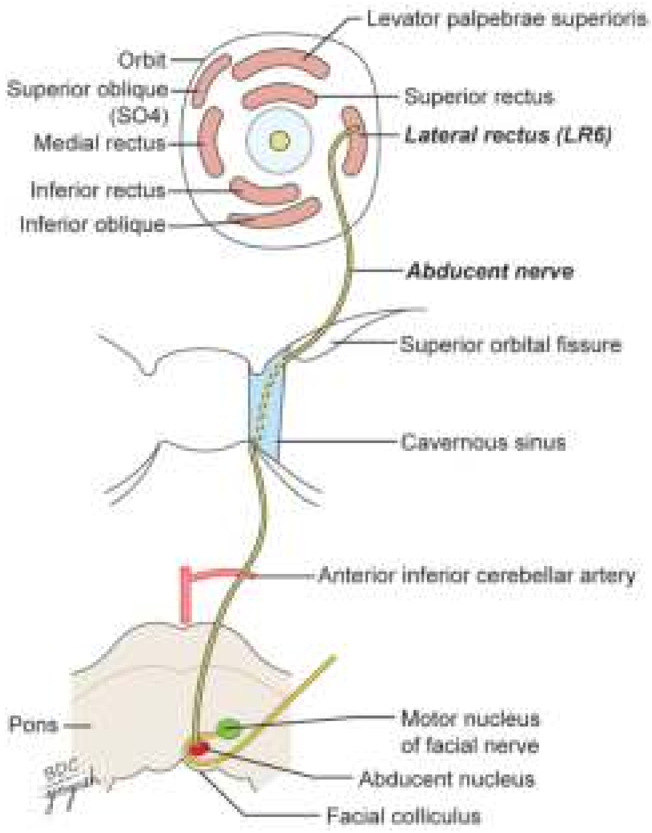

Levator palpebrae superioris
Orbit
Superior oblique (SO4)
Superior rectus
Medial rectus
Lateral rectus (LR6)
Inferior rectus
Inferior oblique
Abducent nerve
Superior orbital fissure
Cavernous sinus
Anterior inferior cerebellar artery
Pons
Motor nucleus of facial nerve
Abducent nucleus
Facial colliculus

Fig. 6.19: The origin, course and distribution of the abducent nerve

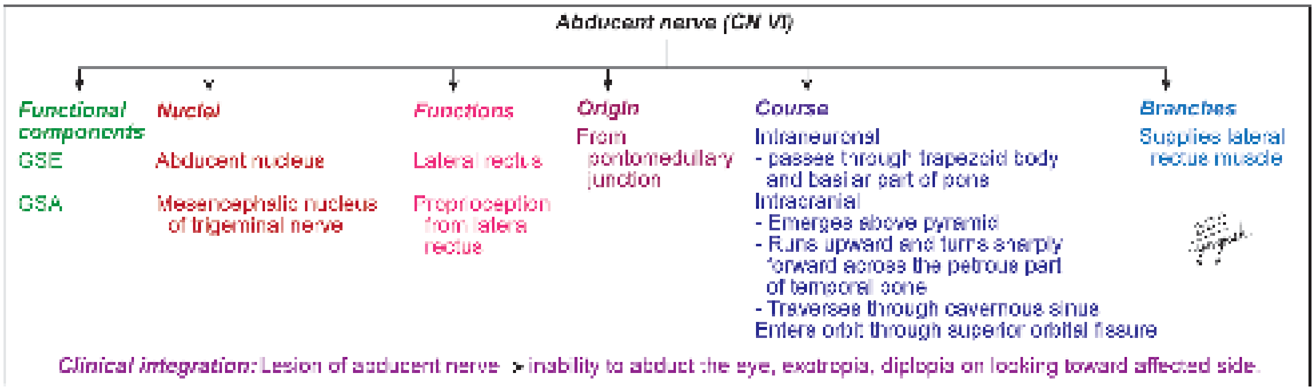
Nucleus

Abducent nucleus is situated in the upper part of the floor of fourth ventricle in the lower pons, beneath the facial colliculus. Ventromedially, it is closely related to the medial longitudinal bundle. Connections of the nucleus are similar to those of the third nerve, except for the pretectal nuclei.

Origin of Nerve

The abducent nerve is attached to the brainstem between the lower border of pons and upper end of medulla (at the pontomedullary junction). Here, the nerve lies medial to the facial 7th nerve.

Flowchart 6.9: Abducent nerve (CN VI)


Abducent nerve (CN VI)
Functional components
GSE
GSA
Nuclei
Abducent nucleus
Mesencephalic nucleus of trigeminal nerve
Functions
Lateral rectus
Proprioception from lateral rectus
Origin
From pontomedullary junction
Course
Intraneuronal
- passes through trapezoid body and basilar part of pons
Intracranial
- Emerges above pyramid
- Runs upward and turns sharply forward across the petrous part of temporal bone
- Traverses through cavernous sinus
Enters orbit through superior orbital fissure
Branches
Supplies lateral rectus muscle
Clinical integration: Lesion of abducent nerve → inability to abduct the eye, exotropia, diplopia on looking toward affected side.

Course and Distribution

The course of abducent nerve is divided into three parts:

1. Intraneuronal course
2. Intracranial course
3. Intraorbital course.

Intraneuronal course: The nucleus of abducent nerve is located in the pons, in the floor of 4th ventricle deep to the facial colliculus. The fibres arising from the nucleus run ventrally and downwards through the trapezoid body and basilar part of the pons.

Intracranial course: Abducent nerve has the longest intracranial course. It emerges at the pontomedullary junction, just at the upper border of pyramid of the medulla. Then, the nerve runs upward, forward and laterally in front of pons and dorsal to the anterior inferior cerebellar artery. Abducent nerve pierces the dura mater lateral to the dorsal sellae to enter the cavernous sinus. Here, the nerve takes sharp forwards turn across the upper border of petrous part of temporal bone. The nerve traverses the cavernous sinus, at first lateral to the internal carotid artery and then inferolateral to the artery. It enters the orbit through the tendinous ring, through the middle part of the superior orbital fissure.

Intraorbital course: In the orbit, the nerve lies below the two divisions of oculomotor nerve and nasociliary nerve. Then the nerve runs forwards and laterally over the ocular surface of the lateral rectus muscle and supplies this muscle.

Branch

The abducent nerve supplies only 1 muscle – lateral rectus.

CLINICAL NEUROANATOMY

- ***Lesions of abducent nerve:*** The abducent nerve is damaged commonly in the increased intracranial pressure due to the following reasons:
  1. Long intracranial course
  2. Sharp bending over the sharp upper border of petrous temporal bone.
  3. Due to these reasons, the abducent nerve is stretched due to the descent of brainstem in the increased intracranial pressure.

  Effects of lesions: The paralysis of abducent nerve results in the paralysis of the lateral rectus muscle which causes (Fig. 6.20):
  1. Inability to abduct the eye
  2. Exotropia (convergent squint) due to unopposed action of the medial rectus
  3. Diplopia on looking toward the affected side.

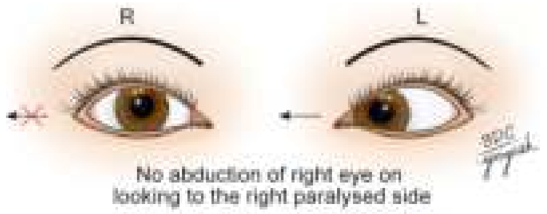

R
L
No abduction of right eye on looking to the right paralysed side

Fig. 6.20: Paralysis of right sixth nerve

FIFTH CRANIAL NERVE (TRIGEMINAL NERVE)

The fifth cranial nerve (trigeminal nerve) is the largest cranial nerve. It comprises three branches, two of which are purely sensory and third, the largest branch is mixed nerve. Trigeminal nerve is the nerve of first brachial arch (Fig. 6.21 and Flowchart 6.10).

Functional Components and Nuclei

1. *Special visceral efferent* (*SVE*) *fibres* from *motor nucleus of trigeminal nerve* (located in upper part of pons). They supply the muscle of first pharyngeal arch.
2. *General somatic afferent* (*GSA*) *fibres* terminate in three nuclei:
   a. *Spinal nucleus of Vth nerve*: It extends from pons to second cervical spinal segment. It receives pain and temperature sensation from most of the face.
   b. *Principal sensory nucleus of Vth nerve*: It lies in dorsolateral region of tegmentum of upper part of the pons. It receives touch and pressure sensations from face and head.

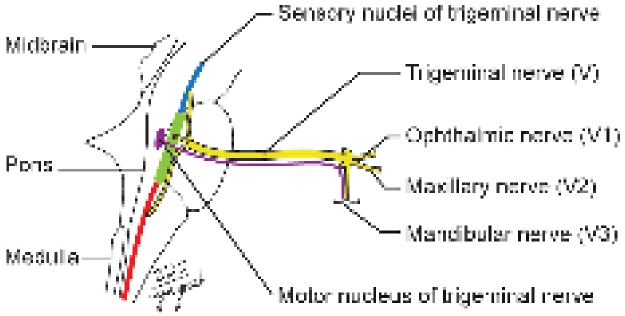
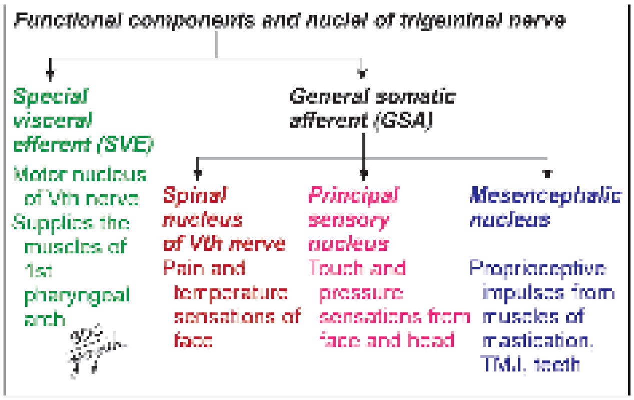

Sensory nuclei of trigeminal nerve
Midbrain
Trigeminal nerve (V)
Ophthalmic nerve (V1)
Pons
Maxillary nerve (V2)
Mandibular nerve (V3)
Medulla
Motor nucleus of trigeminal nerve

Fig. 6.21: Nuclei of trigeminal nerve


Functional components and nuclei of trigeminal nerve
Special visceral efferent (SVE)
Motor nucleus of Vth nerve
Supplies the muscles of 1st pharyngeal arch
General somatic afferent (GSA)
Spinal nucleus of Vth nerve
Pain and temperature sensations of face
Principal sensory nucleus
Touch and pressure sensations from face and head
Mesencephalic nucleus
Proprioceptive impulses from muscles of mastication, TMJ, teeth

Flowchart 6.10: Functional components and nuclei of trigeminal nerve

c. *Mesencephalic nucleus of Vth nerve*: It lies in the periaqueductal grey matter in the midbrain. It receives proprioceptive impulses from muscles of mastication, temporomandibular joint and teeth.

Origin of Nerve

The trigeminal nerve arises by two roots from the pons at its junction with the middle cerebellar peduncle. The roots are:

1. Large, lateral sensory root
2. Smaller, medial motor root.

Course and Distribution

The trigeminal nerve runs forwards and laterally over the apex of petrous part of temporal bone to enter the middle cranial fossa. It forms the enlargement called *trigeminal ganglion*.

Branches:

1. Ophthalmic nerve
2. Maxillary nerve
3. Mandibular nerve.

Ganglia Related to Trigeminal Nerve

Four peripheral parasympathetic ganglia are topographically related to trigeminal nerve:

1. *Ciliary ganglion* related to occulomotor nerve (branch to inferior oblique muscle)
2. *Pterygopalatine ganglion* is related to maxillary nerve
3. *Otic ganglion* related to mandibular nerve
4. *Submandibular ganglion* is related to lingual branch of mandibular nerve.

Ophthalmic Nerve Division (Sensory)

The ophthalmic (V1) nerve is the smallest branch of trigeminal nerve (others are maxillary and mandibular nerves). The ophthalmic nerve is purely *sensory* nerve (Figs 6.22 a and b). It arises from the anterolateral aspect of trigeminal ganglion in the middle cranial fossa. Then the nerve enters the lateral wall of the cavernous sinus and runs forwards below the trochlear nerve and above the maxillary nerve. In the lateral wall of cavernous sinus, the ophthalmic nerve divides into three terminal branches: Lacrimal, frontal, and nasociliary (*Mnemonic*: LFN). All the branches enter the orbit through the superior orbital fissure.

Branches of Ophthalmic Nerve

1. Frontal nerve:
   a. Supratrochlear: Upper eyelid, conjunctiva and lower part of forehead
   b. Supraorbital: Frontal air sinus, upper eyelid, forehead and scalp till vertex
2. Nasociliary nerve:
   a. Branch to ciliary ganglion
   b. 2–3 long ciliary nerves: Sensory to eyeball
   c. Posterior ethmoidal: Sphenoidal air sinus, posterior ethmoidal air sinuses
   d. Intratrochlear: Both eyelids, side of nose and lacrimal sac
   e. Anterior ethmoidal:
      – Middle and anterior ethmoidal sinuses
      – Medial internal nasal
      – Lateral internal nasal
      – External nasal: Skin of ala of vestibule and tip of nose.
3. Lacrimal nerve:
   a. Branch to upper eyelid
   b. Secretomotor fibres to the lacrimal gland.

Maxillary Nerve Division (Sensory)

It is a branch of trigeminal nerve that arises from the trigeminal ganglion. It arises from the trigeminal ganglion, runs forwards in the lateral wall of the cavernous sinus below the ophthalmic nerve. It leaves the middle cranial fossa by passing through the foramen rotundum. Next, the nerve crosses the upper part of pterygopalatine fossa, beyond which it is continued as the *infraorbital nerve*.

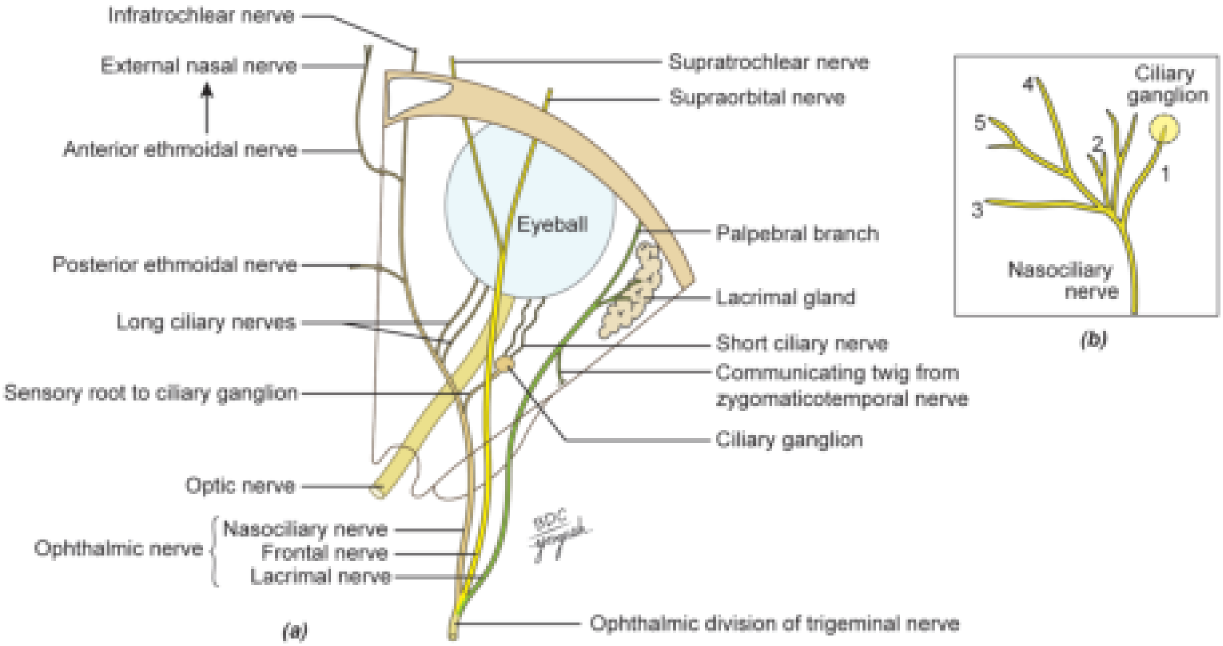
Branches of Maxillary Nerve (Fig. 6.23)

In the middle cranial fossa

Meningeal branch.

In the pterygopalatine fossa

1. Ganglionic branches
2. Posterior superior alveolar nerves
3. Zygomatic nerve
   a. Zygomaticotemporal nerve
   b. Zygomaticofacial nerve.


Infratrochlear nerve
External nasal nerve
Anterior ethmoidal nerve
Posterior ethmoidal nerve
Long ciliary nerves
Sensory root to ciliary ganglion
Optic nerve
Ophthalmic nerve
Nasociliary nerve
Frontal nerve
Lacrimal nerve
(a)
Supratrochlear nerve
Supraorbital nerve
Eyeball
Palpebral branch
Lacrimal gland
Short ciliary nerve
Communicating twig from zygomaticotemporal nerve
Ciliary ganglion
Ophthalmic division of trigeminal nerve
Ciliary ganglion
4
5
2
1
3
Nasociliary nerve
(b)

Figs 6.22a and b: (a) Branches and distribution of the ophthalmic nerve and (b) schematic representation (1. Branch to ciliary ganglion, 2. Long ciliary nerves, 3. Posterior ethmoidal nerve, 4. Intratrochlear nerve, 5. Anterior ethmoidal nerve)

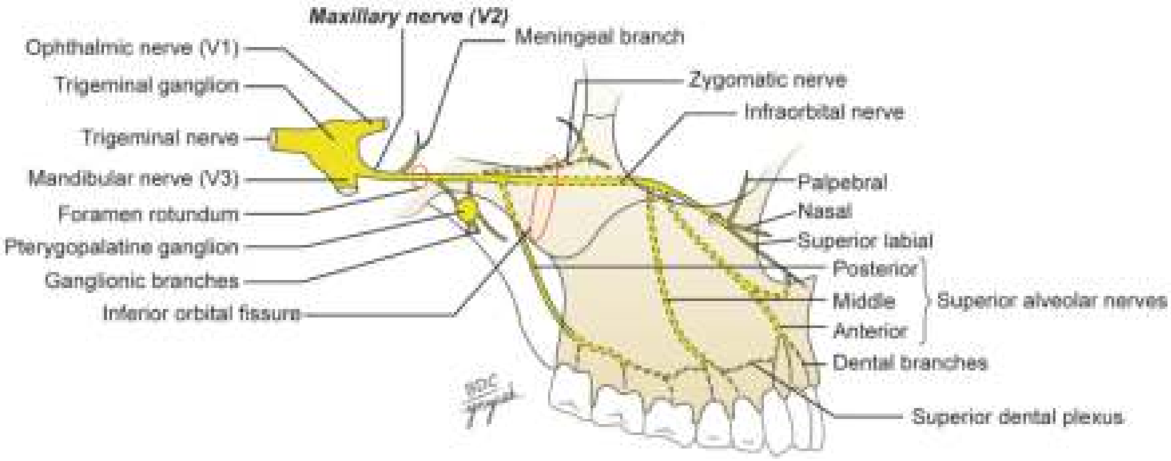

Maxillary nerve (V2)
Meningeal branch
Ophthalmic nerve (V1)
Trigeminal ganglion
Trigeminal nerve
Mandibular nerve (V3)
Foramen rotundum
Pterygopalatine ganglion
Ganglionic branches
Inferior orbital fissure
Zygomatic nerve
Infraorbital nerve
Palpebral
Nasal
Superior labial
Posterior
Middle
Anterior
Superior alveolar nerves
Dental branches
Superior dental plexus

Fig. 6.23: Branches and distribution of the maxillary nerve

Branches through infraorbital nerve

A. *In the infraorbital canal:*
  1. Middle superior alveolar nerve
  2. Anterior superior alveolar nerve
     a. Dental branches
     b. Nasal branches

B. *On the face:*
  1. Palpebral branch
  2. Nasal branch
  3. Superior labial branch.

Mandibular Nerve Division (Sensory and Motor)

It is the largest branch of trigeminal nerve. It consists of sensory and motor fibres. It is the nerve of 1st pharyngeal arch. The mandibular nerve begins in the middle cranial fossa by two roots: Sensory root from the trigeminal ganglion, and the motor root from the pons. The motor root is smaller, and it lies deep to the trigeminal ganglion and the sensory root.

Both the roots pass downwards through the foramen ovale and unite immediately below the foramen to form the main nerve trunk. The mandibular nerve lies in the infratemporal fossa. Here, it lies on the tensor veli palatini, deep to the lateral pterygoid muscle. To visualize the main trunk, remove the upper head of lateral pterygoid muscle carefully. It divides into a small anterior and large posterior trunk (Fig. 6.24).

Branches of Mandibular Nerve

Branches from main trunk

1. Nervus spinosus (meningeal branch)
2. Nerve to medial pterygoid: It supplies—
   a. Medial pterygoid
   b. Tensor veli palatini
   c. Tensor tympani

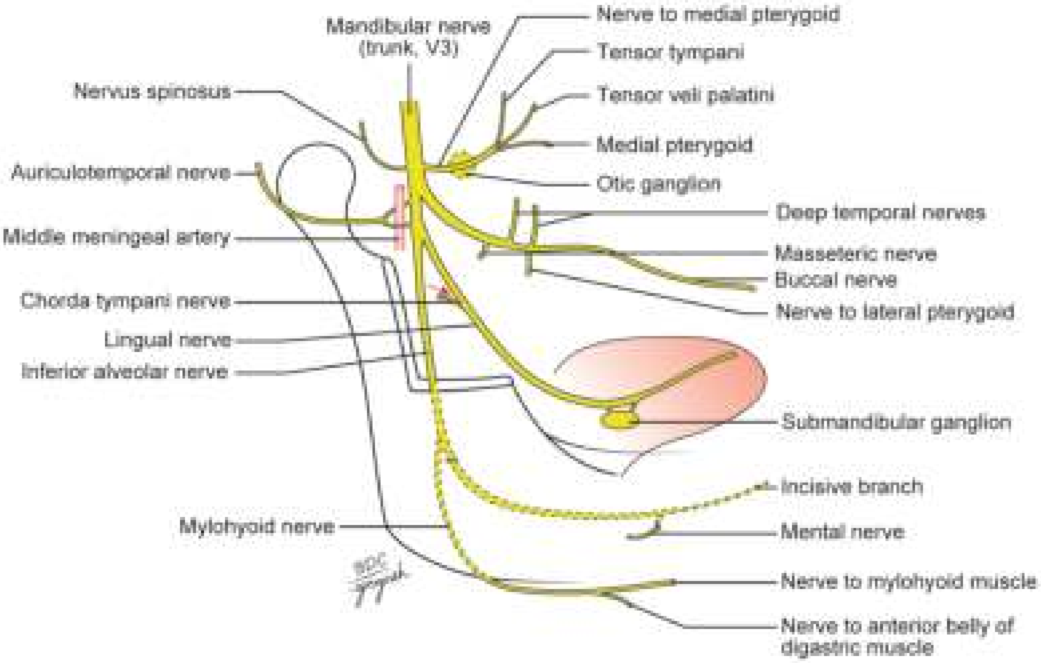

Mandibular nerve (trunk, V3)
Nervus spinosus
Auriculotemporal nerve
Middle meningeal artery
Chorda tympani nerve
Lingual nerve
Inferior alveolar nerve
Mylohyoid nerve
Nerve to medial pterygoid
Tensor tympani
Tensor veli palatini
Medial pterygoid
Otic ganglion
Deep temporal nerves
Masseteric nerve
Buccal nerve
Nerve to lateral pterygoid
Submandibular ganglion
Incisive branch
Mental nerve
Nerve to mylohyoid muscle
Nerve to anterior belly of digastric muscle

Fig. 6.24: Course and distribution of the mandibular nerve

From anterior division

1. Masseteric nerves – for masseter
2. Deep temporal nerves – for temporalis
3. Nerve to lateral pterygoid
4. Buccal nerve for skin of cheek and buccal mucosa.

From posterior division

1. Auriculotemporal nerve
   a. Auricular branch
   b. Temporal branch
   c. Parasympathetic fibres from otic ganglion
2. Lingual nerve
   a. Sensory to anterior 2/3rd of tongue
   b. Via chorda tympani – carries special sensation (taste) from anterior 2/3rd of tongue and parasympathetic fibres to submandibular and sublingual glands.
3. Inferior alveolar nerve
   a. Mylohyoid nerve – for mylohyoid and anterior belly of digastric
   b. Branches to lower teeth and gum
   c. Mental nerve – to skin of chin, lower lip, gum, and canine and incisor teeth.

CLINICAL NEUROANATOMY

- The separate location of main sensory nucleus and spinal nucleus accounts for ***dissociated sensory loss***, i.e. low pontine or medullary lesion will result in loss of pain and temperature sensation while light sensation is preserved. Low pontine, medullary and cervical lesions produce a characteristic '***onion skin***' distribution of pinprick and temperature loss (Fig. 6.25).

Sensory examination

- An ascending lesion spares the openings of nose and mouth (muzzle area) till last.
- Test with pinprick, temperature and light touch over each side of the whole face.
- The sensations in three branches of V nerve can be tested clinically.

Motor examination

- Look for wasting or thinning of temporalis muscle. There may be 'hollowing out' of the temporal fossa.
- Ask patient to press upper and lower teeth together and feel for temporalis and masseter muscles.
- Ask patient to open the mouth. If pterygoid muscles are weak, the jaw would deviate to weak side as the normal muscles will push the jaw to the weak side.

In injury to

- *Ophthalmic nerve:* There is loss of corneal blink reflex (Fig. 6.26) This reflex is mediated by V1 which is afferent pathway and VII nerve which subserves as efferent pathway.
- *Maxillary nerve:* There is loss of sneeze reflex. This branch is the afferent path of sneeze reflex. Efferent pathway of sneeze reflex is nucleus ambiguus, respiratory centre in medulla oblongata, phrenic nerve nucleus, motor cells of spinal cord for intercostal muscles.
- *Mandibular nerve:* There is loss of jaw jerk reflex (Fig. 6.27). Flaccid paralysis of muscles of mastication in injury of mandibular nerve leading to decrease strength for biting. Hypoacusis, i.e. partial deafness to low-pitched sounds due to paralysis of tensor tympani muscle.

Trigeminal neuralgia

- Pain along the distribution of the nerve which is caused due to local lesion or unknown cause. The principal disease affecting sensory root of V nerve is characterized by attacks of severe pain in the area of distribution of maxillary or mandibular divisions. Maxillary nerve is most frequently involved.

- The trigeminal ganglion harbours the herpes simplex virus causing herpes (shingles) in the distribution of the nerve.

Frey's syndrome

1. Penetrating wounds of parotid gland may damage both auriculotemporal and great auricular nerves.
2. During regeneration, the two nerves join with each other.
3. While eating, drops of perspiration appear on skin over parotid gland.

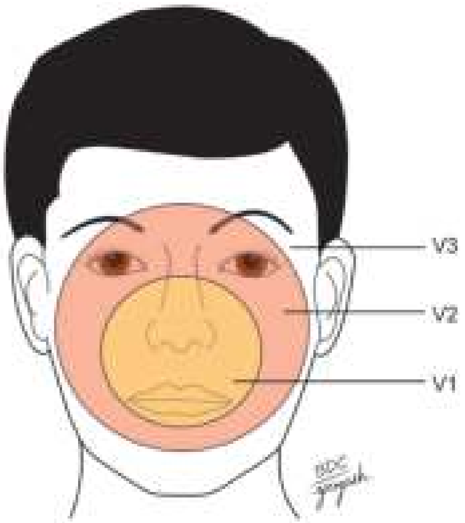


Fig. 6.25: Brainstem lesion of trigeminal nerve (V1: Ophthalmic, V2: Maxillary, V3: Mandibular branches)

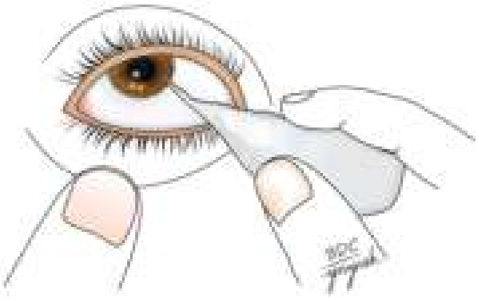


Fig. 6.26: Testing the corneal blink reflex

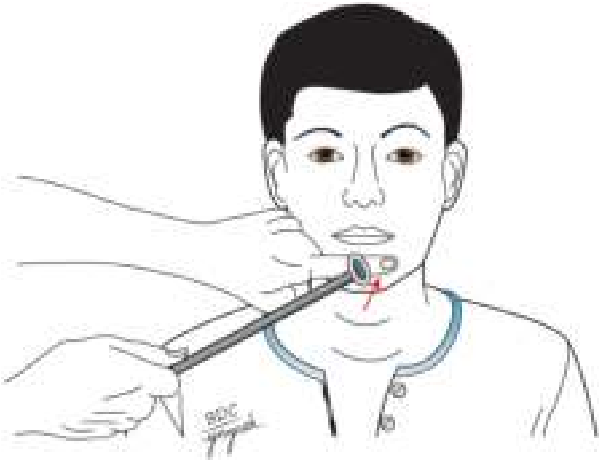


Fig. 6.27: Elicitation of jaw jerk reflex

SEVENTH CRANIAL NERVE (FACIAL NERVE)

Facial nerve is the nerve of the second branchial arch. It supplies mainly the supplies the muscles of facial expressions (Figs 6.28 to 6.31 and Flowchart 6.11 and 6.12).

Functional Components

1. *Special visceral efferent* (*SVE*) *fibres* arise from *motor nucleus of facial nerve* and supplies the muscles derived from the 2nd pharyngeal arch.
2. *General visceral efferent* (*GVE*) *fibres* are preganglionic parasympathetic fibres. They arise from lacrimatory and superior salivatory nucleus of pons and relay at the pterygopalatine and submandibular ganglia for lacrimation and salivation, respectively. The postganglionic fibres of the pterygopalatine ganglion supply the lacrimal gland through zygomatic branch of trigeminal nerve. The postganglionic fibres arising from the submandibular ganglion supply the submandibular and sublingual salivary glands.
3. *Special visceral afferent* (*SVA*) *fibres* carry the taste sensations from anterior two-thirds of the tongue except vallate papillae to the upper part of the nucleus of tractus solitarius. The cell bodies of these fibres lie in the geniculate ganglion.
4. *General somatic afferent* (*GSA*) *fibres* have their cell bodies in the geniculate ganglion. The peripheral processes of these cells innervate part of the skin of the external ear, while the central processes terminate in the spinal nucleus of trigeminal nerve.

Note: The motor nucleus of the facial nerve lies deep in the reticular formation of the lower pons. The part of the nucleus that supplies muscles of the upper part of the face receives corticonuclear fibres from the motor cortex of both the right and left sides. In contrast, the part of the nucleus that supplies muscles of the lower part of the face, receives corticonuclear fibres only from the opposite cerebral hemisphere.

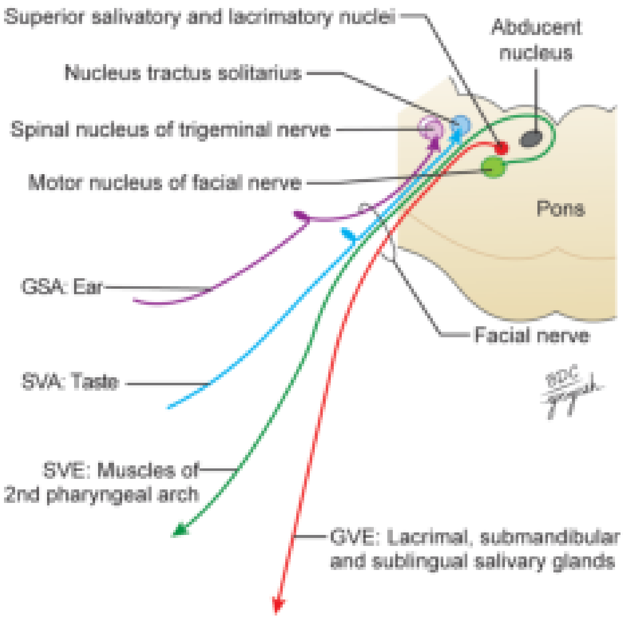

Superior salivatory and lacrimatory nuclei
Abducent nucleus
Nucleus tractus solitarius
Spinal nucleus of trigeminal nerve
Motor nucleus of facial nerve
Pons
GSA: Ear
Facial nerve
SVA: Taste
SVE: Muscles of 2nd pharyngeal arch
GVE: Lacrimal, submandibular and sublingual salivary glands

Fig. 6.28: Facial nerve nuclei (transverse section passing through the pons, at the level of facial colliculus)

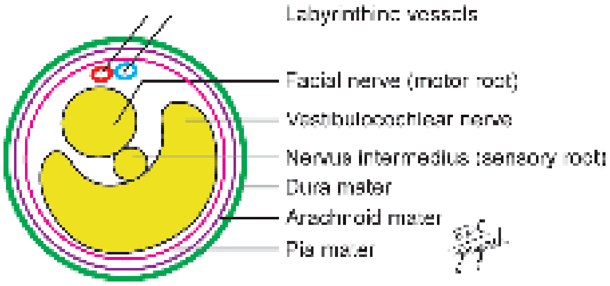

Labyrinthine vessels
Facial nerve (motor root)
Vestibulocochlear nerve
Nervus intermedius (sensory root)
Dura mater
Arachnoid mater
Pia mater

Fig. 6.29: Structures in the left internal acoustic meatus

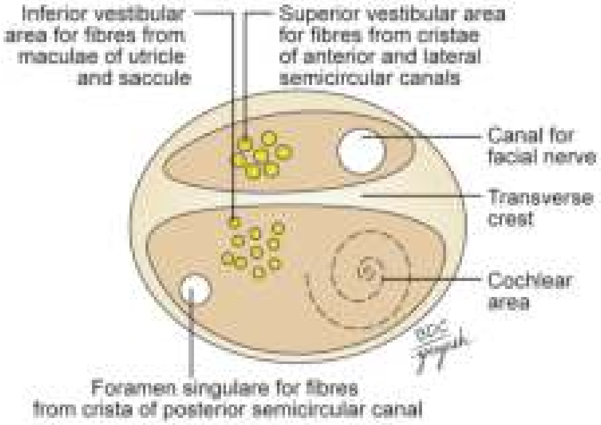

Inferior vestibular area for fibres from maculae of utricle and saccule
Superior vestibular area for fibres from cristae of anterior and lateral semicircular canals
Canal for facial nerve
Transverse crest
Cochlear area
Foramen singulare for fibres from crista of posterior semicircular canal

Fig. 6.30: Some features seen on the fundus of the left internal acoustic meatus

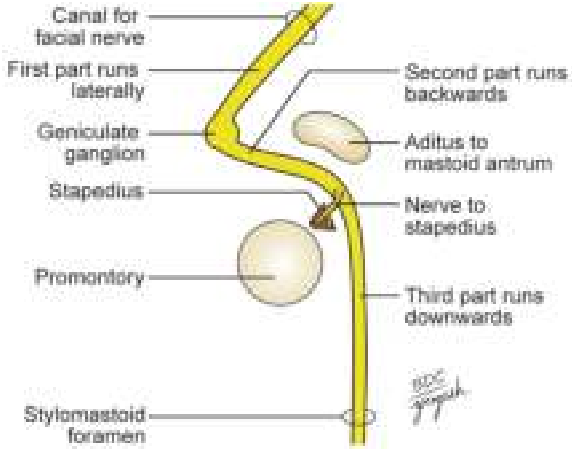

Canal for facial nerve
First part runs laterally
Geniculate ganglion
Stapedius
Promontory
Stylomastoid foramen
Second part runs backwards
Aditus to mastoid antrum
Nerve to stapedius
Third part runs downwards

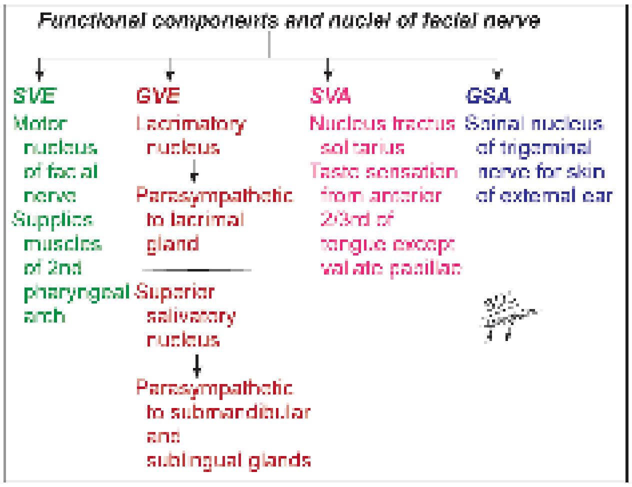
Fig. 6.31: Course of facial nerve

Origin of Nerve

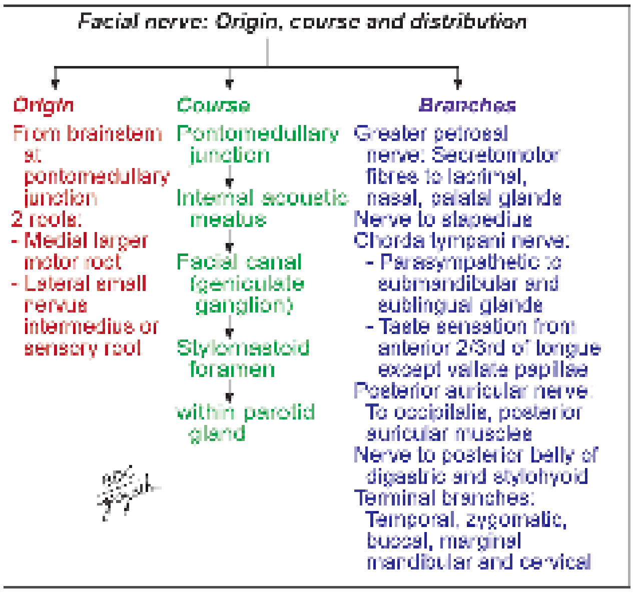
The facial nerve is attached to the brainstem between the lower border of pons and upper end of medulla (at the pontomedullary junction). Here, the nerve lies lateral to abducent nerve and medial to the 8th nerve (Fig. 6.28).

The facial nerve arises by two roots – medial larger motor root and lateral smaller sensory root (***nervus intermedius*** of Weisberg). The roots enter the internal auditory meatus along with vestibulocochlear nerve and labyrinthine vessels. At the lateral end of meatus, two roots unite to form the trunk of the facial nerve.

Flowchart 6.11: Functional components and nuclei of facial nerve


Functional components and nuclei of facial nerve
SVE
Motor nucleus of facial nerve
Supplies muscles of 2nd pharyngeal arch
GVE
Lacrimatory nucleus
Parasympathetic to lacrimal gland
Superior salivatory nucleus
Parasympathetic to submandibular and sublingual glands
SVA
Nucleus tractus solitarius
Taste sensation from anterior 2/3rd of tongue except valate papillae
GSA
Spinal nucleus of trigeminal nerve for skin of external ear

Flowchart 6.12: Facial nerve: Origin, course and distribution


Facial nerve: Origin, course and distribution
Origin
From brainstem at pontomedullary junction
2 roots:
- Medial larger motor root
- Lateral small nervus intermedius or sensory root
Course
Pontomedullary junction
Internal acoustic meatus
Facial canal (geniculate ganglion)
Stylomastoid foramen
within parotid gland
Branches
Greater petrosal nerve: Secretomotor fibres to lacrimal, nasal, palatal glands
Nerve to stapedius
Chorda tympani nerve:
- Parasympathetic to submandibular and sublingual glands
- Taste sensation from anterior 2/3rd of tongue except vallate papillae
Posterior auricular nerve: To occipitalis, posterior auricular muscles
Nerve to posterior belly of digastric and stylohyoid
Terminal branches: Temporal, zygomatic, buccal, marginal mandibular and cervical

Course and Relations

1. *In the meatus*, the motor root lies in a groove on the eighth nerve, with the sensory root intervening. Here the seventh and eighth nerves are accompanied by the labyrinthine vessels. At the bottom or fundus of the meatus, the two roots, sensory and motor, fuse to form a single trunk, which lies in the petrous temporal bone (Figs 6.29 and 6.30).
2. Within the canal, the course of the nerve can be divided into three parts by two bends (Fig. 6.31).

   The first part is directed laterally above the vestibule; the second part runs backwards in relation to the medial wall of the middle ear, above the promontory. The third part is directed vertically downwards behind the promontory.

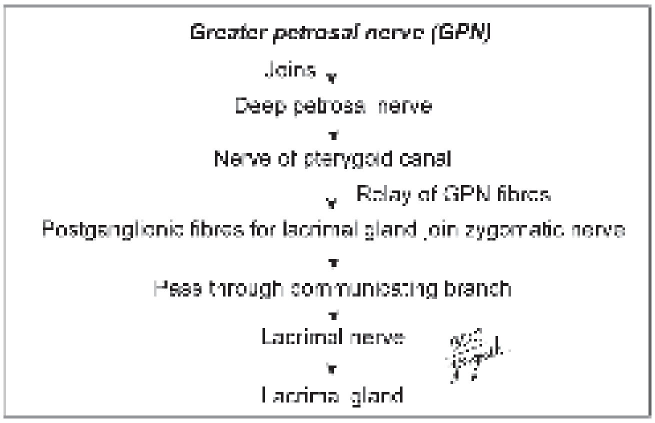
   The first bend at the junction of the first and second parts is sharp. It lies over the anterosuperior part of the promontory, and is also called the *genu*. The ***geniculate ganglion*** of the nerve is so-called because it lies on the genu. The second bend is gradual, and lies between the promontory and the aditus to the mastoid antrum.

3. The facial nerve leaves the skull by passing through the stylomastoid foramen.
4. In its ***extracranial course***, the facial nerve crosses the lateral side of the base of the styloid process. It enters the posteromedial surface of the parotid gland, and runs forwards through the gland crossing the retromandibular vein and the external carotid artery. Behind the neck of the mandible, it divides into its five terminal branches which emerge along the anterior border of the parotid gland.

Branches and Distribution (Fig. 6.32)

1. Within the bony facial canal:
   a. Greater petrosal nerve
   b. Nerve to the stapedius
   c. Chorda tympani.
2. At its exit from the stylomastoid foramen:
   a. Posterior auricular
   b. Digastric
   c. Stylohyoid.
3. Terminal branches within the parotid gland:
   a. Temporal
   b. Zygomatic
   c. Buccal
   d. Marginal mandibular
   e. Cervical.

Flowchart 6.13: Tracing nerve supply of lacrimal gland


Greater petrosal nerve (GPN)
Joins
Deep petrosal nerve
Nerve of pterygoid canal
Relay of GPN fibres
Postganglionic fibres for lacrimal gland join zygomatic nerve
Pass through communicating branch
Lacrimal nerve
Lacrimal gland

4. Communicating branches with adjacent cranial and spinal nerves.

Greater petrosal nerve—course has been traced in Flowchart 6.13.

Note:

The ***nerve to the stapedius*** arises opposite the pyramid of the middle ear, and supplies the stapedius muscle. The muscle dampens excessive vibrations of the stapes caused by high-pitched sounds. In paralysis of the muscle, even normal sounds appear too loud and is known as *hyperacusis*.

The ***chorda tympani nerve*** arises in the vertical part of the facial canal about 6 mm above the stylomastoid foramen. It runs upwards and forwards in a bony canal. It enters the middle ear and runs forwards in close relation to the tympanic membrane. It leaves

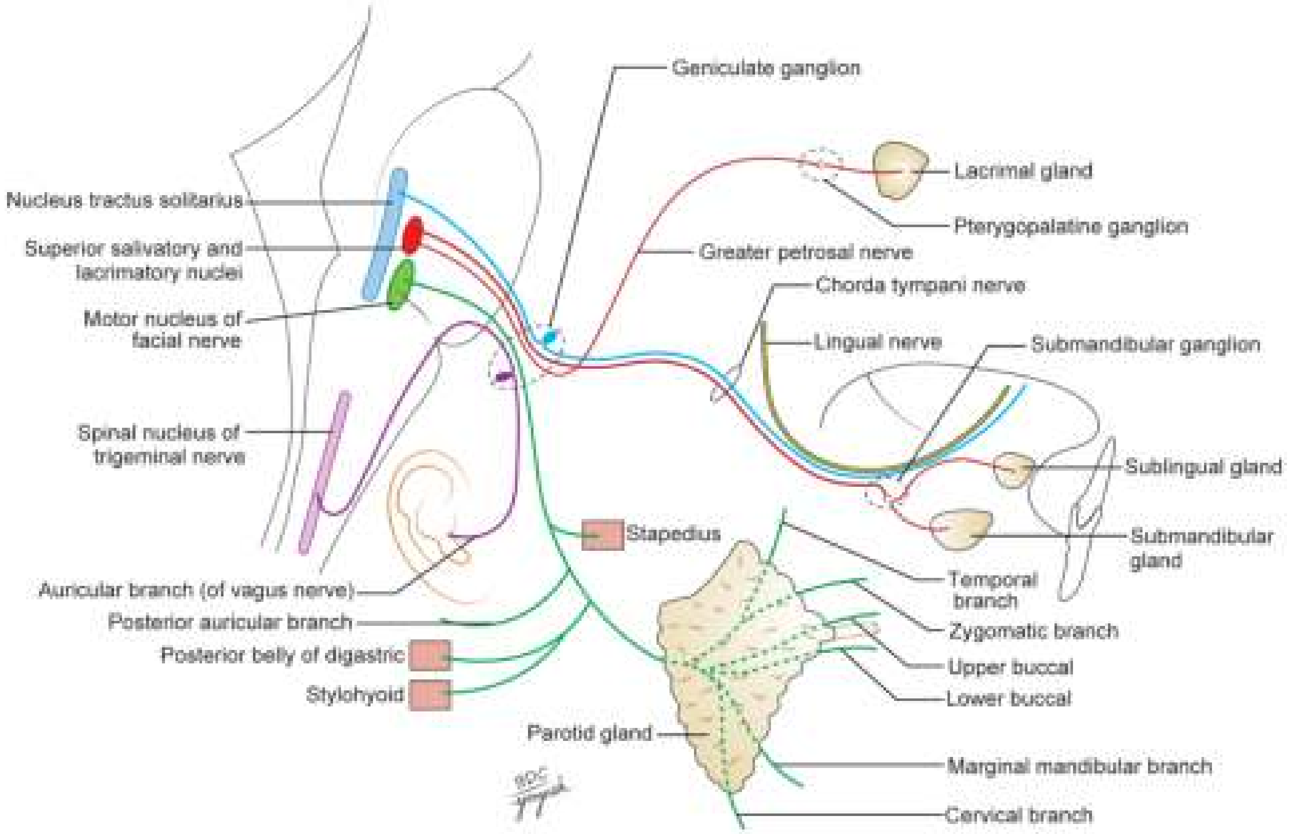

Geniculate ganglion
Lacrimal gland
Pterygopalatine ganglion
Nucleus tractus solitarius
Superior salivatory and lacrimatory nuclei
Greater petrosal nerve
Chorda tympani nerve
Motor nucleus of facial nerve
Lingual nerve
Submandibular ganglion
Spinal nucleus of trigeminal nerve
Sublingual gland
Stapedius
Submandibular gland
Temporal branch
Auricular branch (of vagus nerve)
Posterior auricular branch
Zygomatic branch
Posterior belly of digastric
Upper buccal
Stylohyoid
Lower buccal
Parotid gland
Marginal mandibular branch
Cervical branch

Fig. 6.32: Distribution of functional components of VII nerve

the middle ear by passing through the petrotympanic fissure. It then passes medial to the spine of the sphenoid and enters the infratemporal fossa. Here it joins the lingual nerve through which chorda tympani nerve is distributed. It carries:

a. Preganglionic secretomotor fibres to the submandibular ganglion for supply of the submandibular and sublingual salivary glands.
b. Taste fibres from the anterior two-thirds of the tongue except circumvallate papillae.

The *posterior auricular nerve* arises just below the stylomastoid foramen. It ascends between the mastoid process and the external acoustic meatus, and supplies:

a. Auricularis posterior
b. Occipitalis
c. Intrinsic muscles on the back of auricle.

The *digastric branch* arises close to the previous nerve. It is short and supplies the posterior belly of the digastric.

The *stylohyoid branch* arises with the digastric branch, is long and supplies the stylohyoid muscle.

The *temporal branches* cross the zygomatic arch and supply:

a. Auricularis anterior
b. Auricularis superior
c. Intrinsic muscles on the lateral side of the ear
d. Frontalis
e. Orbicularis oculi
f. Corrugator supercilii.

The *zygomatic branches* run across the zygomatic bone and supply the lower part of orbicularis oculi.

The *buccal branches* are two in number. The upper buccal branch runs above the parotid duct and the lower buccal branch below the duct. They supply muscles in that vicinity especially the buccinator.

The *marginal mandibular branch* runs below the angle of the mandible deep to the platysma. It crosses the body of the mandible and supplies muscles of the lower lip and chin.

The *cervical branch* emerges from the apex of the parotid gland, and runs downwards and forwards in the neck to supply the platysma.

Communicating branches: For effective coordination between the movements of the muscles of the first, second and third branchial arches, the motor nerves of the three arches communicate with each other. The facial nerve also communicates with the sensory nerves distributed over its motor territory.

CLINICAL NEUROANATOMY

- ***Bell's palsy:*** Injury to the facial nerve near or outside the stylomastoid foramen produces Bell's palsy (Fig. 6.33). It is lower motor neuron type of paralysis of muscles of facial expressions. It may be due to viral infection or unknown cause.

  Features: The following features are present on the side of paralysis:

  1. Facial asymmetry due to unopposed action of muscle of unaffected side.
  2. Loss of horizontal wrinkles of forehead due to paralysis of occipitofrontalis muscle.
  3. Inability to close the eye and widening of palpebral fissure due to paralysis of orbicularis oculi.
  4. *Epiphora* (spilling of tears on the face) due to paralysis of orbicularis oculi.
  5. Drooping of angle of mouth toward affected side and drooling of saliva due to paralysis of orbicularis oris.
  6. Inability of whistling and accumulation of food in vestibule of mouth due to paralysis of buccinator.
  7. Loss of nasolabial furrow due to paralysis of levator labii superioris alaeque nasi.

  [***Mnemonics*: *BELL'S Palsy:*** **B**link reflex abnormal, **E**ar ache, **L**acrimation (deficient), **L**oss of taste in anterior two-thirds of tongue, **S**udden onset, **Palsy** of muscles supplied by VII nerve, all symptoms are ipsilateral]

  Note: The facial muscles of the upper half of the face are controlled by both the cerebral hemispheres. The damage to one cerebral hemisphere or the fibres from it to the nucleus of facial nerve cause *supranuclear palsy of facial nerve*. In this type of paralysis, the muscles of the upper half of the face remain unaffected.

- For clinical testing of the facial nerve, and for different types of facial paralysis—infranuclear.

  Facial nerve palsy in newborn: The mastoid process is absent in newborn and stylomastoid foramen is superficial. Manipulation of baby's head during delivery may damage the VII nerve. This leads to paralysis of facial muscles especially the buccinator, required for sucking the milk.

  Crocodile tears syndrome: Lacrimation during eating occurs due to aberrant regeneration after trauma.

- In case of damage to facial nerve proximal to geniculate ganglia, regenerating fibres for submandibular salivary gland grow in endoneurial sheaths of preganglionic secretomotor fibres supplying the lacrimal gland. That is why patient lacrimates while eating food.

  Ramsay-Hunt syndrome: Involvement of geniculate ganglia by herpes zoster results in this syndrome.

  It shows following symptoms:

  a. Hyperacusis
  b. Loss of lacrimation
  c. Loss of sensation of taste in anterior two-thirds of tongue
  d. Bell's palsy and lack of salivation
  e. Vesicles on the auricle.

Ganglia Related to Facial Nerve

The ganglia associated with the facial nerve are as follows:

1. The ***geniculate ganglion*** is located on the first bend of the facial nerve, in relation to the medial wall of the middle ear. It is a *sensory ganglion.* The taste fibres present in the nerve are peripheral processes of pseudounipolar neurons present in the geniculate ganglion.
2. The ***submandibular ganglion*** is a *parasympathetic ganglion* for relay of secretomotor fibres to the submandibular and sublingual glands. The preganglionic fibres come from the chorda tympani nerve (Table 6.3). It is described in Chapter 7 of *BD Chaurasia's Human Anatomy, Volume 3*.

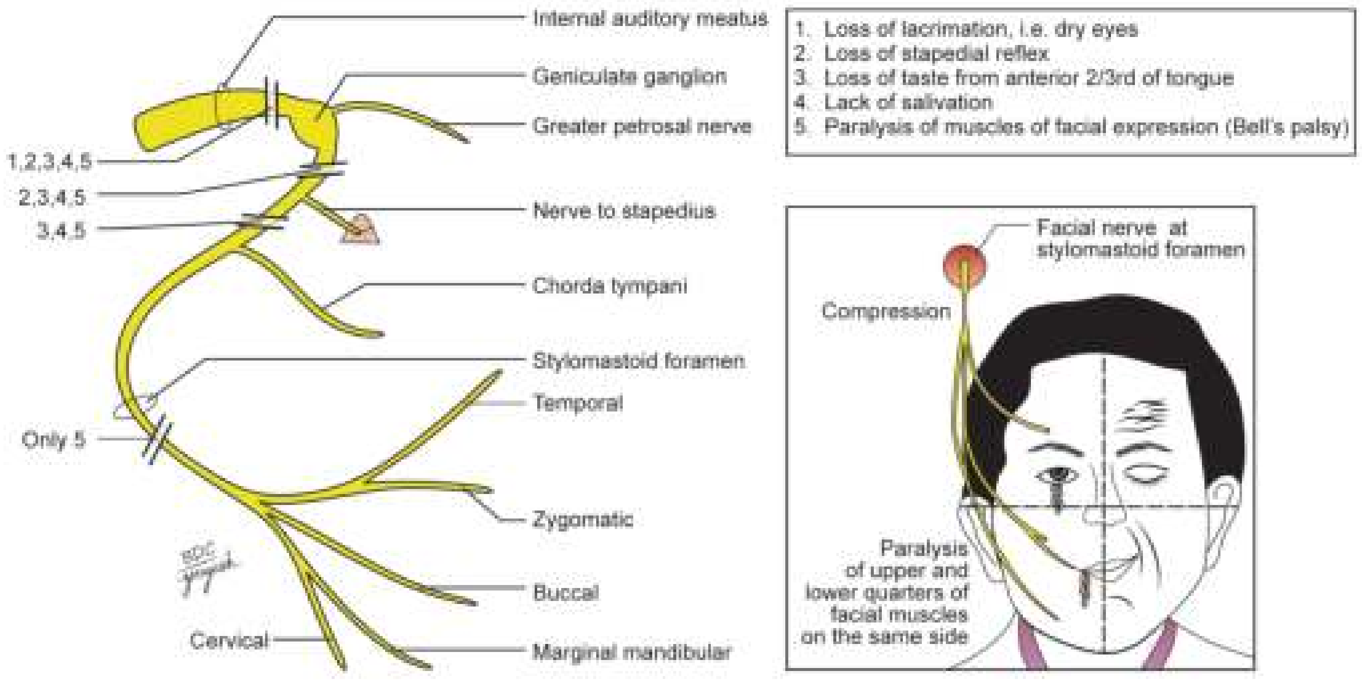

Internal auditory meatus
Geniculate ganglion
Greater petrosal nerve
1,2,3,4,5
2,3,4,5
3,4,5
Nerve to stapedius
Chorda tympani
Stylomastoid foramen
Temporal
Only 5
Zygomatic
Buccal
Cervical
Marginal mandibular
1. Loss of lacrimation, i.e. dry eyes
2. Loss of stapedial reflex
3. Loss of taste from anterior 2/3rd of tongue
4. Lack of salivation
5. Paralysis of muscles of facial expression (Bell's palsy)
Facial nerve at stylomastoid foramen
Compression
Paralysis of upper and lower quarters of facial muscles on the same side

Fig. 6.33: Symptoms according to the level of injury to cranial nerve VII; Inset showing Bell's palsy

TABLE 6.3: Connections of parasympathetic ganglia

Ganglia	*Sensory root*	*Sympathetic root*	*Secretomotor parasympathetic root*	*Motor root*	*Distribution*
Ciliary	From nasociliary nerve	Plexus along ophthalmic artery	Edinger-Westphal nucleus → oculomotor nerve → nerve to inferior oblique	—	Ciliaris muscles Sphincter pupillae
Otic	Branch from auriculotemporal nerve	Plexus along middle meningeal artery	Inferior salivatory nucleus → glossopharyngeal nerve → tympanic branch → tympanic plexus → lesser petrosal nerve	Branch from nerve to medial pterygoid	Secretomotor to parotid gland via auriculotemporal nerve Tensor veli palatini and tensor tympani via nerve to medial pterygoid (unrelayed)
Pterygopalatine	Two branches from maxillary nerve	Deep petrosal from plexus around internal carotid artery	Lacrimatory nucleus → nervus intermedius → facial nerve → geniculate ganglion → greater petrosal nerve + deep petrosal = nerve of pterygoid canal	—	Mucous glands of nose, paranasal sinuses, palate, nasopharynx Some fibres pass through zygomatic nerve → zygomatico nerve temporal nerve → communicating branch to lacrimal nerve → lacrimal gland
Submandibular	Two branches from lingual nerve	Branch from plexus around	Superior salivatory nucleus → facial nerve → chorda tympani facial artery → joins the lingual nerve	—	Submandibular, sublingual and anterior lingual glands

3. The ***pterygopalatine ganglion*** is also a *parasympathetic ganglion*. Secretomotor fibres meant for the lacrimal gland relay in this ganglion. The fibres reach the ganglion from the nerve to the pterygoid canal (Table 6.3). It is described in Chapter 15 of *BD Chaurasia's Human Anatomy, Volume 3*.

EIGHTH CRANIAL NERVE
(VESTIBULOCOCHLEAR NERVE)

This nerve comprises hearing and vestibular parts.

Functional Components

Special somatic afferent fibres: They carry sensory information of:

1. Equilibrium to the vestibular nucleus of brainstem.
2. Hearing to the dorsal and ventral cochlear nuclei located in pons.

Ganglion

1. ***Vestibular or Scarpa's ganglion*** is located on the vestibular nerve in the lateral part of the internal acoustic meatus. It consists of bipolar neurons.
2. ***Cochlear or spiral ganglion*** is located in modiolus. It also consists bipolar neurons.

Origin Nerve

Vestibulocochlear nerve is attached to the pontomedullary junction, lateral to the facial nerve.

Course and Relations

Vestibulocochlear nerve emerges at the pontomedullary junction and runs laterally to enter internal acoustic meatus along with facial nerve and labyrinthine vessels.

1. ***Vestibular part*****:** As it is sensory nerve, the nerve begins from the macula of utricle, ampullary crests of semicircular canals, and macula of saccule. These fibres are peripheral processes of bipolar neurons of vestibular ganglion. The central processes of these neurons form vestibular nerve. The fibres terminate at the vestibular nuclei of the brainstem.
2. ***Cochlear part*** begins from the organ of Corti. These are the peripheral processes of the bipolar neurons of spiral ganglion. The central processes of these neurons form cochlear nerve which terminates at the ventral and dorsal cochlear nuclei of pons.

Pathway of Hearing (Figs 6.34 to 6.36)

1. The first neurons of the pathway are located in the ***spiral ganglion***. They are ***bipolar***. Their peripheral processes innervate the spiral organ of Corti (Fig. 6.34), while central processes form the cochlear nerve (Fig. 6.35). This nerve terminates in the dorsal and ventral cochlear nuclei.
2. The second neurons lie in the dorsal and ventral cochlear nuclei. Most of the axons arising in these nuclei cross to the opposite side (in the trapezoid body) and terminate in the superior olivary nucleus. (Many fibres end in the nucleus of trapezoid body or of the lateral lemniscus.) Some fibres are uncrossed.
3. The third neurons lie in the superior olivary nucleus. Their axons form the lateral lemniscus and reach the inferior colliculus.
4. The fourth neurons lie in the inferior colliculus. Their axons pass through the inferior brachium to reach the medial geniculate body (Some fibres of lateral lemniscus reach the medial geniculate body without relay in the inferior colliculus).
5. The fifth neurons lie in the medial geniculate body. Their axons form the auditory radiation, which passes through the sublentiform part of the internal capsule to reach the auditory area (Fig. 6.36) in the temporal lobe.

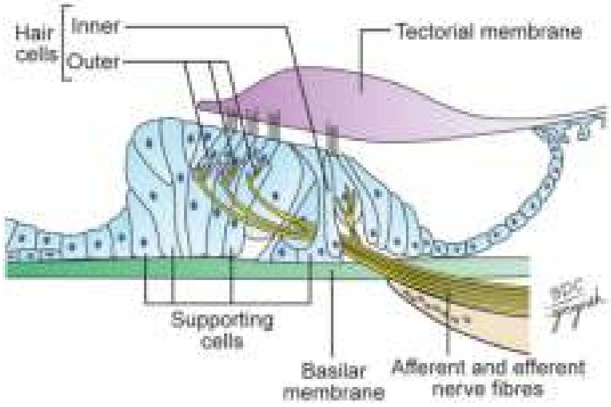

Hair cells
Inner
Outer
Tectorial membrane
Supporting cells
Basilar membrane
Afferent and efferent nerve fibres

Fig. 6.34: Organ of Corti

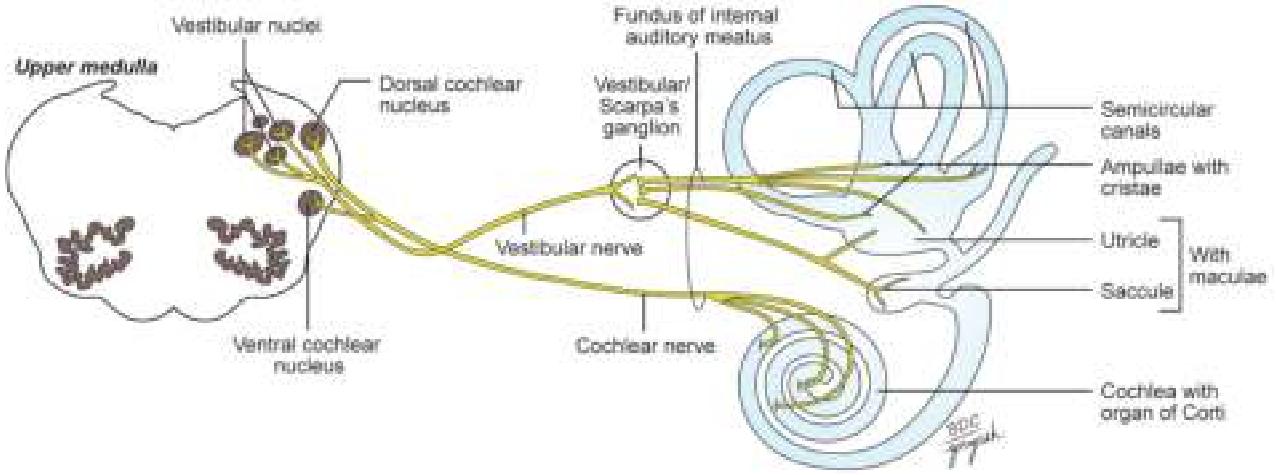

Vestibular nuclei
Upper medulla
Dorsal cochlear nucleus
Fundus of internal auditory meatus
Vestibular/ Scarpa's ganglion
Semicircular canals
Ampullae with cristae
Utricle
Saccule
With maculae
Vestibular nerve
Ventral cochlear nucleus
Cochlear nerve
Cochlea with organ of Corti

Fig. 6.35: Course of cochlear and vestibular nerves

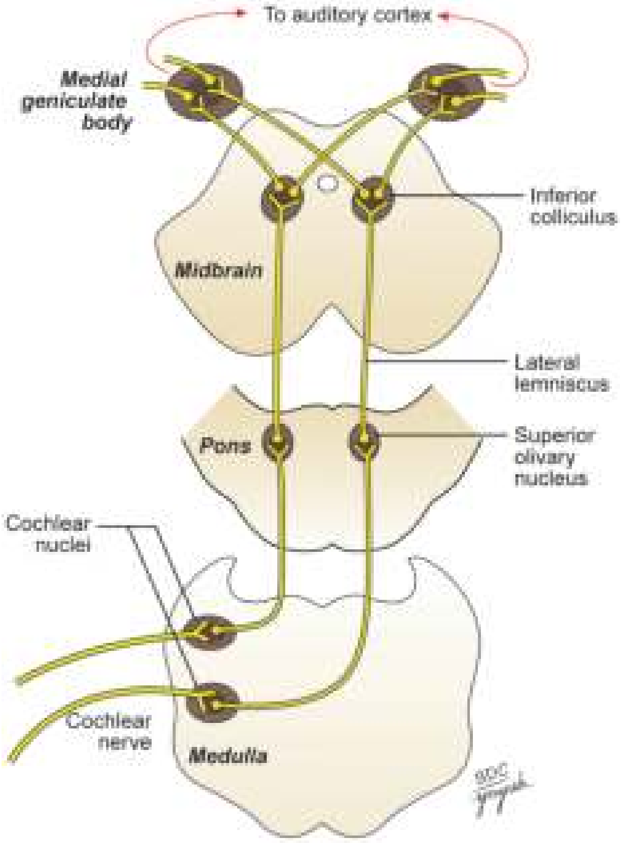

To auditory cortex
Medial geniculate body
Inferior colliculus
Midbrain
Lateral lemniscus
Pons
Superior olivary nucleus
Cochlear nuclei
Cochlear nerve
Medulla

Fig. 6.36: Auditory pathway

Vestibular Pathway

The vestibular receptors are the maculae (Fig. 6.38) of the saccule and utricle (for static balance) (Figs 6.37a and b) and in the crista of the ampullaris of semicircular ducts (for kinetic balance) (Fig. 6.39). Fibres from cristae of anterior and lateral semicircular canals and some fibres from the two maculae lie in superior vestibular area of internal acoustic meatus.

Fibres of crista of posterior semicircular canal lie in foramen singulare.

Most of the fibres from maculae of utricle and saccule lie in inferior vestibular area.

These three nerve divisions are peripheral processes of bipolar neurons of the vestibular ganglion. This ganglion is situated in the internal acoustic meatus. The central processes arising from the neurons of the ganglion form the vestibular nerve which ends in the vestibular nuclei.

The second neurons in the pathway of balance lie in the vestibular nuclei. These nuclei send fibres:

a. To the archicerebellum through the inferior cerebellar peduncle (vestibulocerebellar tract).
b. To the motor nuclei of the brainstem (chiefly of the III, IV, VI and XI nerves) through the medial longitudinal bundle.
c. To the anterior horn cells of the spinal cord through the vestibulospinal tract.
d. Fibres also reach thalamus and premotor cortex of frontal lobe.

Through the vestibular pathway, the impulses arising in the labyrinth can influence the movements of the eyes, the head, the neck and the trunk (Fig. 6.40).

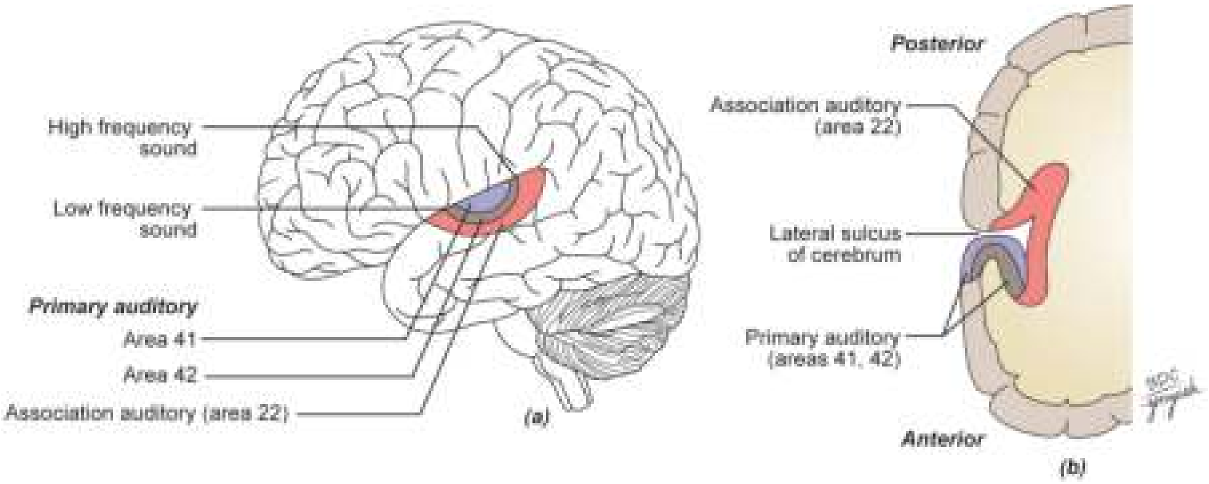
CLINICAL NEUROANATOMY

Deafness: Three types of hearing loss are seen:

1. Conductive deafness is the failure of sound waves to reach the cochlea.
2. Sensorineural deafness is the failure of production or transmission of action potential due to cochlear disease, cochlear nerve disease or defects in cochlear nerve central connections.
3. Cortical deafness is a bilateral or dominant posterior temporal lobe lesion. It results in a failure to understand spoken language even though hearing is preserved.

Vertigo: This is an illusion of rotatory movement due to disturbed orientation of the body in space. The patient feels that the environment is moving. It is due to disease of vestibular nerve.

Tinnitus: It is a sensation of buzzing, ringing, hissing or singing quality. Tinnitus may be unilateral or bilateral; high or low pitch; continuous or intermittent.


High frequency sound
Low frequency sound
Primary auditory
Area 41
Area 42
Association auditory (area 22)
(a)
Posterior
Association auditory (area 22)
Lateral sulcus of cerebrum
Primary auditory (areas 41, 42)
Anterior
(b)

Figs 6.37a and b: Auditory cortex: (a) Posterior ramus of lateral sulcus and (b) depth of lateral sulcus

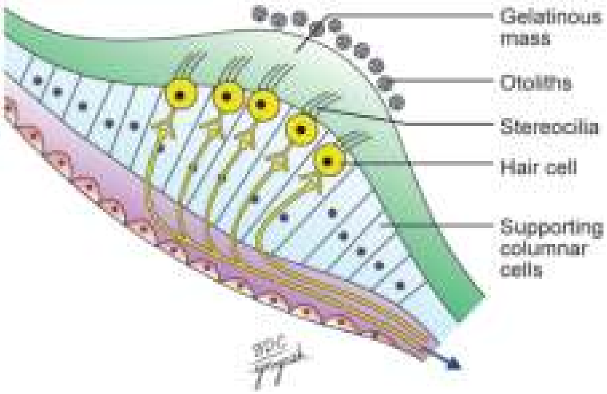

Gelatinous mass
Otoliths
Stereocilia
Hair cell
Supporting columnar cells

Fig. 6.38: Structure of the macula

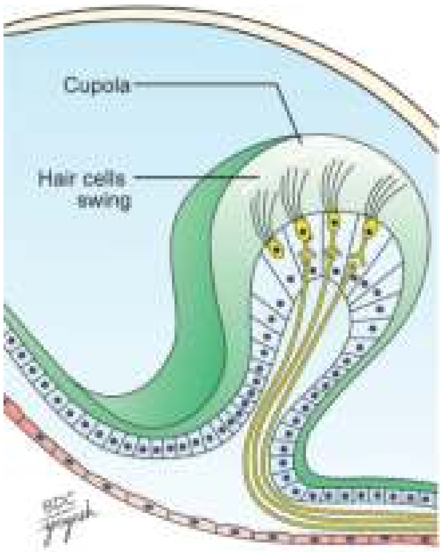

Cupola
Hair cells swing

Fig. 6.39: Structure of crista ampullaris

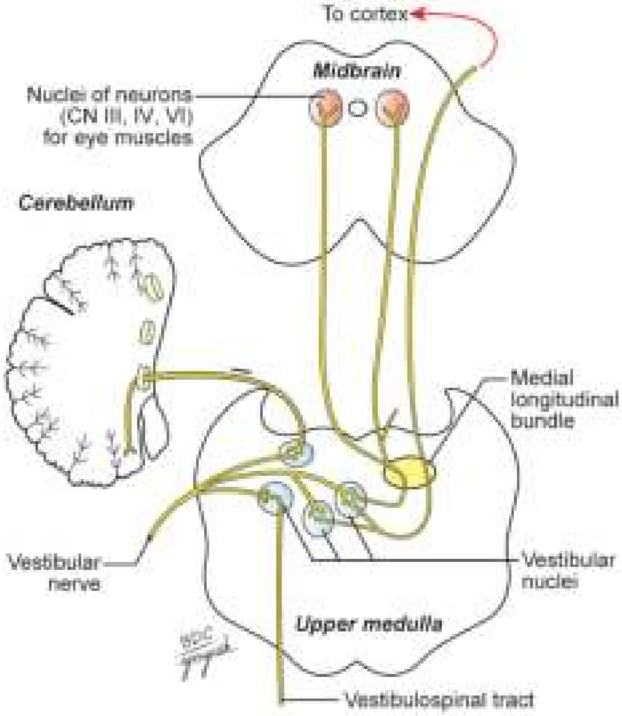

To cortex
Midbrain
Nuclei of neurons (CN III, IV, VI) for eye muscles
Cerebellum
Medial longitudinal bundle
Vestibular nerve
Vestibular nuclei
Upper medulla
Vestibulospinal tract

Fig. 6.40: Vestibular pathway

Meniere's syndrome: It is characterised by recurrent attacks of tinnitus, vertigo and hearing loss accompanied by a sensitivity to noises. It affects middle-aged or older persons. In this condition, there is an increase in volume of endolymph.

Acoustic neuroma: It is a slow growing benign tumour of neurolemmal cells. It causes an early loss of hearing.

NINTH CRANIAL NERVE
(GLOSSOPHARYNGEAL NERVE)

Glossopharyngeal nerve is the ninth cranial nerve (Fig. 6.41 and Flowchart 6.14). It is the nerve of the third branchial arch.

It is motor to the stylopharyngeus. It is secretomotor to the parotid gland and gustatory to the posterior one-third of the tongue including the circumvallate papillae.

It is sensory to the pharynx, the tonsil, soft palate, the posterior one-third of the tongue, carotid body and carotid sinus.

Functional Components

1. ***Special visceral efferent*** (*SVE*) *fibres* arise from the *nucleus ambiguus*. They supply stylopharyngeus muscle (muscle of 3rd pharyngeal arch).
2. ***General visceral efferent*** (*GVE*) *fibres* arise from the *inferior salivatory nucleus*. These are preganglionic parasympathetic fibres that relay in otic ganglion and supply the parotid gland.
3. ***General visceral afferent*** (*GVA*) *fibres* carry general sensation from pharynx, palate, posterior one-third of tongue, tonsil, carotid body, and carotid sinus. These sensations are carried to the *nucleus tractus solitarius*.
4. ***Special visceral afferent*** (*SVA*) *fibres* carry taste sensation from the posterior one-third of tongue including circumvallate papillae. They carry sensation to the *nucleus tractus solitarius*.
5. ***General somatic afferent*** (*GSA*) *fibres* carry general sensation from middle ear, proprioceptive sensation from stylopharyngeus to the *nucleus of spinal tract of trigeminal nerve*.

Nuclei

The three nuclei in the upper part of medulla are:

1. Nucleus ambiguus (branchiomotor)
2. Inferior salivatory nucleus (parasympathetic)
3. Nucleus of tractus solitarius (gustatory).

Ganglia of Glossopharyngeal Nerve

The glossopharyngeal nerve has two sensory ganglia: Smaller superior and larger inferior ganglion. They contain cell bodies for sensory fibres.

Origin of Nerve

The glossopharyngeal nerve arises by 3–4 rootlets which are attached to the posterolateral sulcus of medulla, just above the rootlets of vagus nerve (Fig. 6.42).

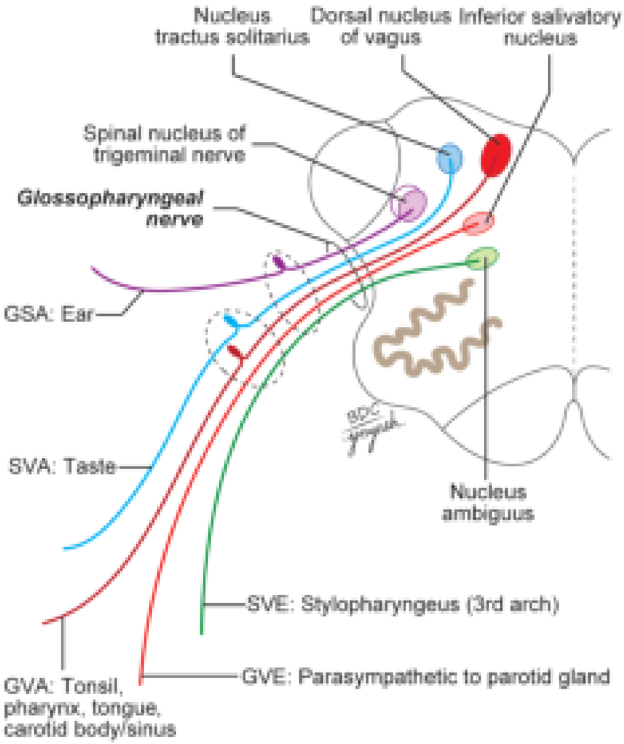
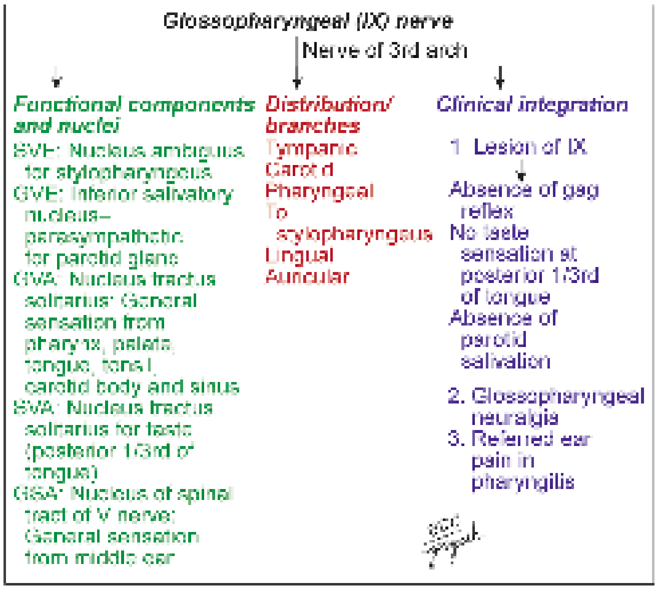

Nucleus tractus solitarius
Dorsal nucleus of vagus
Inferior salivatory nucleus
Spinal nucleus of trigeminal nerve
Glossopharyngeal nerve
GSA: Ear
SVA: Taste
Nucleus ambiguus
SVE: Stylopharyngeus (3rd arch)
GVE: Parasympathetic to parotid gland
GVA: Tonsil, pharynx, tongue, carotid body/sinus

Fig. 6.41: Functional components and nuclei of IX cranial nerve (transverse section passing through the medulla oblongata, superior and inferior ganglia of glossopharyngeal nerve are shown in dotted line)

Flowchart 6.14: Glossopharyngeal (IX) nerve


Glossopharyngeal (IX) nerve

Nerve of 3rd arch

Functional components and nuclei
SVE: Nucleus ambiguus for stylopharyngeus
GVE: Inferior salivatory nucleus–parasympathetic for parotid gland
GVA: Nucleus tractus solitarius: General sensation from pharynx, palate, tongue, tonsil, carotid body and sinus
SVA: Nucleus tractus solitarius for taste (posterior 1/3rd of tongue)
GSA: Nucleus of spinal tract of V nerve: General sensation from middle ear

Distribution/ branches
Tympanic
Carotid
Pharyngeal
To stylopharyngeus
Lingual
Auricular

Clinical integration
1. Lesion of IX
Absence of gag reflex
No taste sensation at posterior 1/3rd of tongue
Absence of parotid salivation
2. Glossopharyngeal neuralgia
3. Referred ear pain in pharyngitis

(SVE: Special visceral efferent, GVE: General visceral efferent, GVA: General visceral afferent, SVA: Special visceral afferent, GSA: General somatic afferent)

Course and Relations

1. In **their** ***intraneural course***, the fibres of the nerve pass forwards and laterally, between the olivary nucleus and the inferior cerebellar peduncle, through the reticular formation of the medulla.
2. At the base of the brain, the nerve is attached by 3 to 4 filaments to the upper part of the posterolateral sulcus of the medulla, just above the rootlets of the vagus nerve.

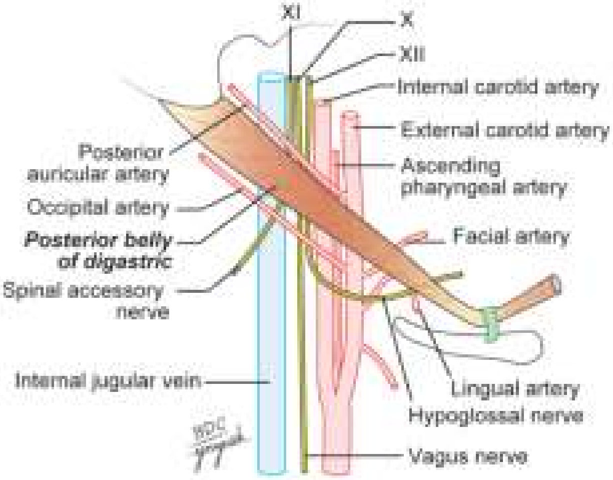

XI
X
XII
Internal carotid artery
External carotid artery
Ascending pharyngeal artery
Facial artery
Posterior auricular artery
Occipital artery
Posterior belly of digastric
Spinal accessory nerve
Internal jugular vein
Lingual artery
Hypoglossal nerve
Vagus nerve

Fig. 6.42: Relation of cranial nerves IX, X, XI, and XII to carotid arteries and internal jugular vein

3. In their intracranial course, the filaments unite to form a single trunk which passes forwards and laterally towards the jugular foramen, crossing and grooving the jugular tubercle of the occipital bone.
4. The nerve *leaves the skull* by passing through the middle part of the *jugular foramen*, anterior to the vagus and accessory nerves. It has a separate sheath of dura mater.
5. In the jugular foramen, the nerve is lodged in a deep groove leading to the cochlear canaliculus, and is separated from the vagus and accessory nerves by the inferior petrosal sinus.

   In its ***extracranial course***, the nerve descends:
   a. Between the internal jugular vein and the internal carotid artery, deep to the styloid process and the muscles attached to it.
   b. It then turns forwards winding round the lateral aspect of the stylopharyngeus, passes between the external and internal carotid arteries, and reaches the side of the pharynx. Here it gives pharyngeal branches.
   c. It enters the submandibular region by passing deep to the hyoglossus, where it breaks up into tonsillar and lingual branches.
6. At the base of skull, ninth nerve presents a superior ganglion and an inferior ganglion. Superior ganglion is a detached part of the inferior ganglion, and gives no branches. The inferior ganglion is larger, occupies notch on the lower border of petrous temporal, and gives out communicating and tympanic branches.

Branches and Distribution (Fig. 6.43)

1. *Tympanic branch*: It carries sensation from the mucous membrane of the tympanic cavity, tympanic membrane, mastoid antrum, mastoid air cells and most of the auditory tube. The preganglionic parasympathetic fibres of tympanic branch (fibres from inferior salivatory nucleus) supply the parotid glands through otic ganglion.

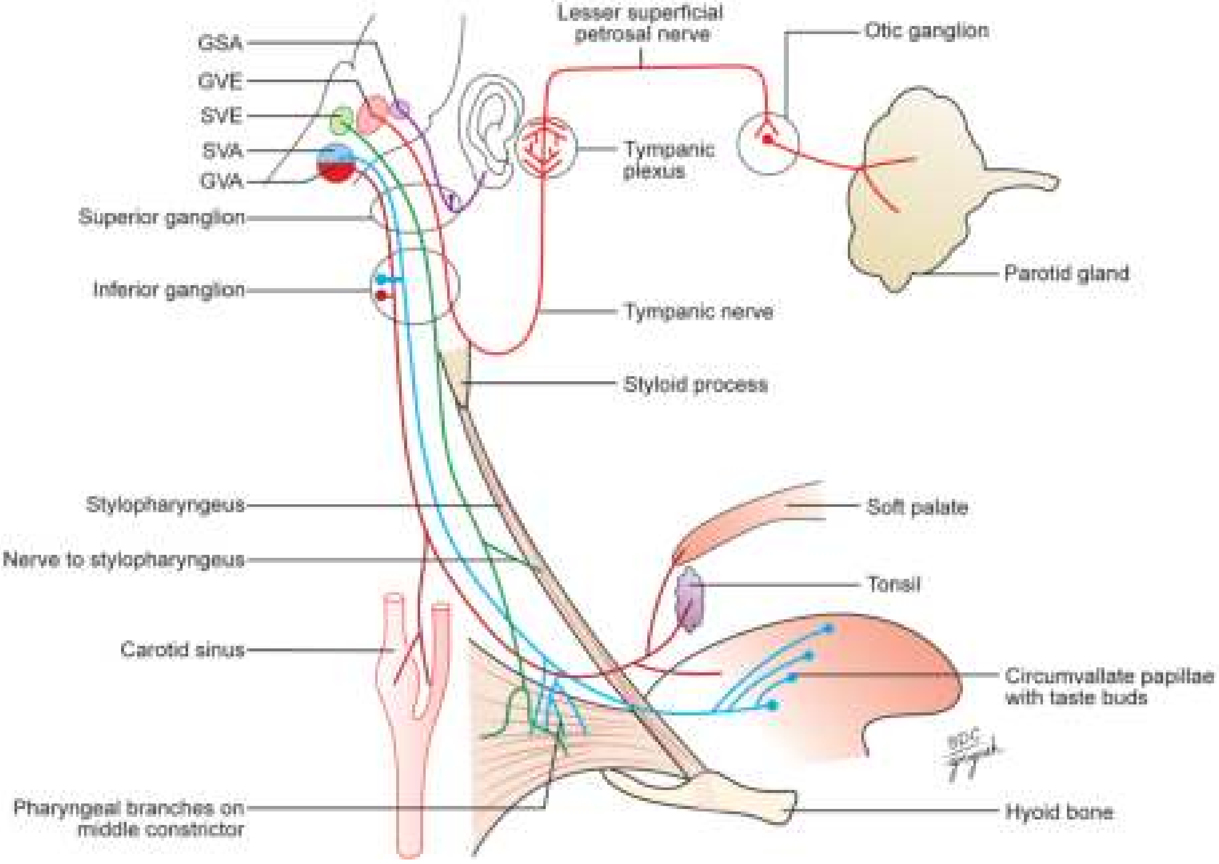

GSA
GVE
SVE
SVA
GVA
Superior ganglion
Inferior ganglion
Stylopharyngeus
Nerve to stylopharyngeus
Carotid sinus
Pharyngeal branches on middle constrictor
Lesser superficial petrosal nerve
Otic ganglion
Tympanic plexus
Parotid gland
Tympanic nerve
Styloid process
Soft palate
Tonsil
Circumvallate papillae with taste buds
Hyoid bone

Fig. 6.43: Distribution of functional components of glossopharyngeal nerve

2. *Carotid branch* to the carotid sinus and carotid body.
3. *Pharyngeal branches* from pharyngeal plexus and carry sensation from mucosa of the pharynx.
4. *Muscular branch* to stylopharyngeus muscle (muscle of 3rd pharyngeal arch)
5. *Tonsillar branches* supply palatine tonsil, soft plate, and palatoglossal arches.
6. *Lingual branches* supply the posterior one-third of the tongue and circumvallate papillae and carry both taste and general sensations.
7. *Auricular branch* supplies the pinna of the ear and the external auditory meatus. The cell bodies of these sensory neurons are located in the superior ganglion of the glossopharyngeal nerve.

CLINICAL NEUROANATOMY

- ***Clinical testing*** *of glossopharyngeal nerve*: It can be tested clinically by:
  1. ***Eliciting gag reflex***: Normally tickling the posterior wall of pharynx, soft palate or tonsillar fossa, a reflex contraction of pharyngeal muscle occurs. This is called *gag reflex*. It is absent in glossopharyngeal nerve paralysis.
  2. *Testing taste sensation* on the posterior one-third of tongue. It is lost in glossopharyngeal nerve paralysis.
- ***Glossopharyngeal neuralgia:*** It is a short sharp severe attack of pain affecting posterior part of pharynx or tonsillar area.
- ***Lesion of glossopharyngeal nerve*** causes:
  a. Absence of secretions of parotid gland.
  b. Absence of taste from posterior one-third of tongue and the circumvallate papillae.
  c. Loss of pain sensations from tongue, tonsil, pharynx and soft palate.
  d. Gag reflex is absent.
- ***Jugular foramen syndrome*** is due to injury at the jugular foramen resulting in multiple cranial nerve palsies.
- Isolated lesions of the ninth nerve are almost unknown. They are usually accompanied by lesions of the vagus nerve.
- ***Referred pain in pharyngitis:*** The pharyngitis may cause referred pain in the ear as both are supplied by IX nerve. However, in these cases, eustachian catarrh should be excluded.

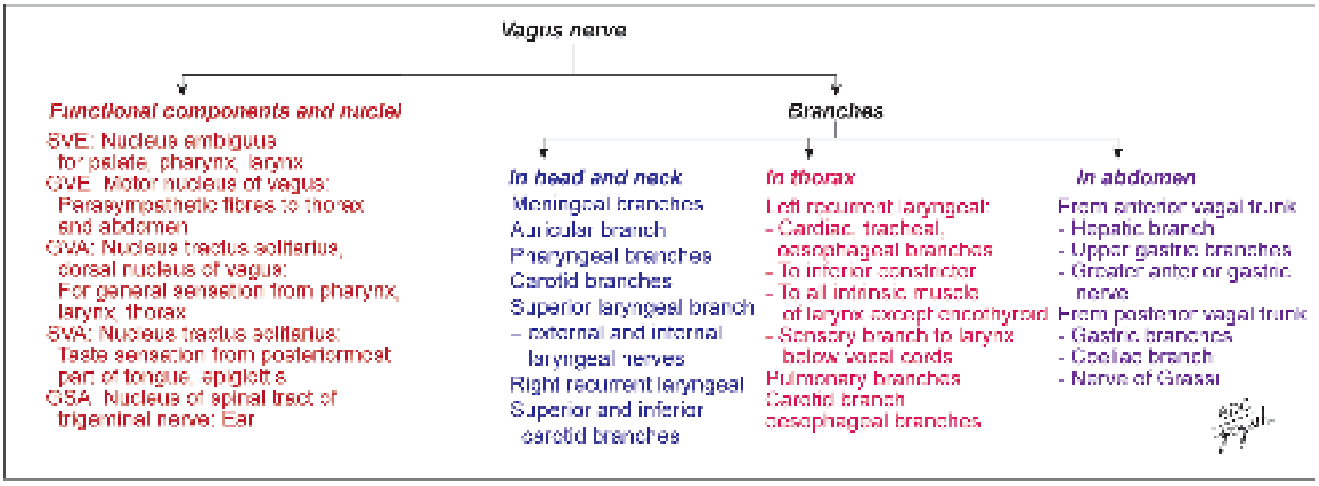
TENTH CRANIAL NERVE (VAGUS NERVE)

Vagus nerve is the tenth cranial nerve. It is so-called because of its extensive ('vague') course, through the head, the neck, the thorax and the abdomen. The fibres of the cranial root of the accessory nerve are also distributed through it (Fig. 6.44 and Flowchart 6.15).

Functional Components

1. ***Special visceral efferent*** (*SVE*) *fibres*: They supply the palate, pharynx, and larynx. They arise from the *nucleus ambiguus*.

Flowchart 6.15: Vagus nerve


Vagus nerve
Functional components and nuclei
SVE: Nucleus ambiguus for palate, pharynx, larynx
GVE: Motor nucleus of vagus: Parasympathetic fibres to thorax and abdomen
GVA: Nucleus tractus solitarius, dorsal nucleus of vagus: For general sensation from pharynx, larynx, thorax
SVA: Nucleus tractus solitarius: Taste sensation from posteriormost part of tongue, epiglottis
GSA: Nucleus of spinal tract of trigeminal nerve: Ear
Branches
In head and neck
Meningeal branches
Auricular branch
Pharyngeal branches
Carotid branches
Superior laryngeal branch – external and internal laryngeal nerves
Right recurrent laryngeal
Superior and inferior carotid branches
In thorax
Left recurrent laryngeal:
- Cardiac, tracheal, oesophageal branches
- To inferior constrictor
- To all intrinsic muscle of larynx except cricothyroid
- Sensory branch to larynx below vocal cords
Pulmonary branches
Carotid branch
oesophageal branches
In abdomen
From anterior vagal trunk
- Hepatic branch
- Upper gastric branches
- Greater anterior gastric nerve
From posterior vagal trunk
- Gastric branches
- Coeliac branch
- Nerve of Grassi

(SVE: Special visceral efferent, GVE: General visceral efferent, GVA: General visceral afferent, SVA: Special visceral afferent, GSA: General somatic afferent)

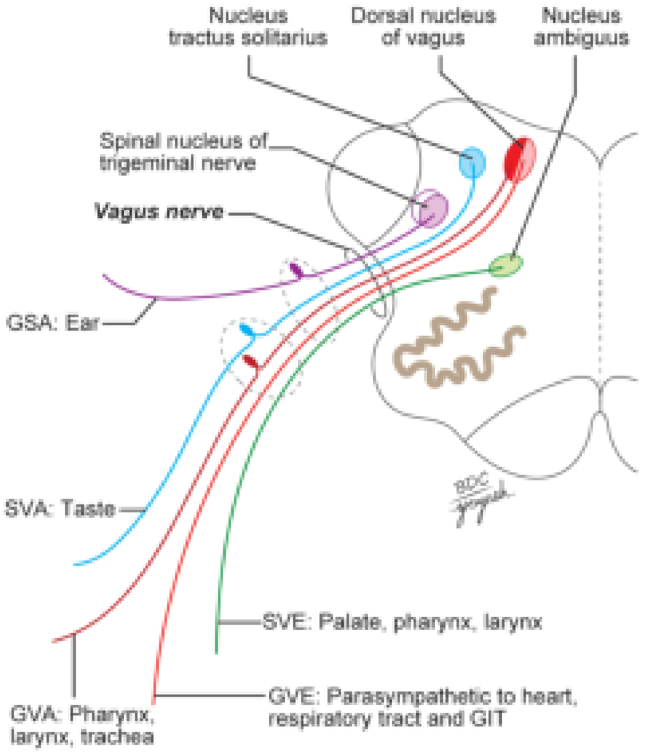

Nucleus tractus solitarius
Dorsal nucleus of vagus
Nucleus ambiguus
Spinal nucleus of trigeminal nerve
Vagus nerve
GSA: Ear
SVA: Taste
SVE: Palate, pharynx, larynx
GVE: Parasympathetic to heart, respiratory tract and GIT
GVA: Pharynx, larynx, trachea

Fig. 6.44: Functional components and nuclei of the vagus nerve (transverse section passing through the medulla oblongata, superior and inferior ganglia of vagus nerve are shown in dotted line)

2. ***General visceral efferent*** (*GVE*) *fibres*: They are preganglionic parasympathetic fibres for thoracic and abdominal viscera. They arise from the dorsal *motor nucleus of vagus*.
3. ***General visceral afferent*** (*GVA*) *fibres*: They carry sensation from pharynx, larynx, oesophagus, carotid body, and from thoracic viscera to the lower part of *nucleus tractus solitarius* and few fibres to the *dorsal nucleus of vagus*.
4. ***Special visceral afferent*** (*SVA*) *fibres*: They carry taste sense from the posterior most part of the tongue and epiglottis to the upper part of *nucleus tractus solitarius*.
5. ***General somatic afferent*** (*GSA*) *fibres*: They carry general sensation from the skin of the external ear to the *spinal nucleus of trigeminal nerve*.

Nuclei

1. *Nucleus ambiguus (branchiomotor):* Mostly a part of the cranial root of accessory nerve; partly of vagus.
2. *Dorsal nucleus of vagus (parasympathetic):* It is a mixed nucleus, being both motor (visceromotor and secretomotor) and sensory (viscerosensory). Its fibres form the main bulk of the nerve.
3. *Nucleus of tractus solitarius (gustatory):* Distributed through internal laryngeal nerve to the taste buds of epiglottis and vallecula.
4. *Nucleus of spinal tract of trigeminal nerve.*

Ganglia of Vagus Nerve

The vagus nerve has two ganglia:

1. ***Smaller superior*** **(*jugular*)** ***ganglion*****:** It lies within the jugular foramen. The superior ganglion contains the cell bodies of pseudounipolar sensory neurons carrying GSA information from the pinna of the ear and external auditory meatus and the dura of the posterior cranial fossa.
2. ***Large inferior ganglion*** **(*nodose ganglion*):** It lies just below the jugular foramen. It contains cell bodies of neurons that carry general visceral afferent sensory innervation from the mucosa of the soft palate, pharynx, and larynx, and a minor SVA (taste) sensation from posteriormost part of the tongue and epiglottis.

Note: The cranial root of the accessory nerve (11th nerve) joins the vagus nerve just below the inferior ganglion.

Origin of Vagus Nerve

The vagus nerve arises by about 10 rootlets from the lateral aspect of the medulla between the olive and inferior cerebellar peduncle (Fig. 6.45). These rootlets

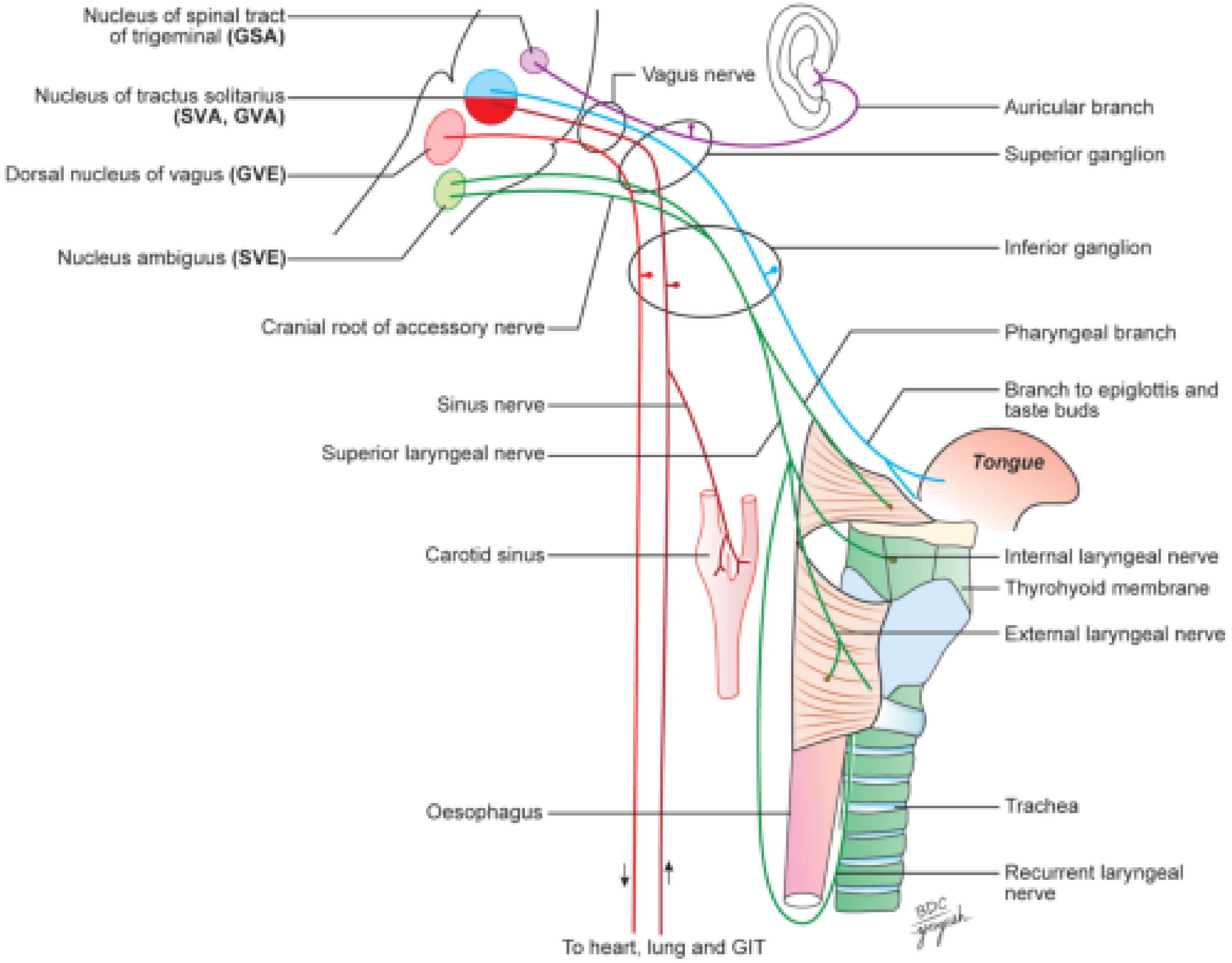

Nucleus of spinal tract of trigeminal (GSA)
Nucleus of tractus solitarius (SVA, GVA)
Dorsal nucleus of vagus (GVE)
Nucleus ambiguus (SVE)
Cranial root of accessory nerve
Sinus nerve
Superior laryngeal nerve
Carotid sinus
Oesophagus
To heart, lung and GIT
Vagus nerve
Auricular branch
Superior ganglion
Inferior ganglion
Pharyngeal branch
Branch to epiglottis and taste buds
Tongue
Internal laryngeal nerve
Thyrohyoid membrane
External laryngeal nerve
Trachea
Recurrent laryngeal nerve

Fig. 6.45: Distribution of functional components of vagus in head and neck

emerge through the posterolateral sulcus of medulla and unite to form a single nerve trunk.

Course and Relations in Head and Neck

1. In the *intracranial course*, fibres run forwards and laterally through the reticular formation of medulla, between the olivary nucleus and inferior cerebellar peduncle.
2. The nerve is attached, by about ten rootlets, to the posterolateral sulcus of medulla.
3. In the intracranial course, the rootlets unite to form a large trunk which passes laterally across the jugular tubercle along with the glossopharyngeal and cranial root of accessory nerves, and reaches the jugular foramen.
4. The nerve *leaves the cranial cavity* by passing through the middle part of the jugular foramen, between the sigmoid and inferior petrosal sinuses. In the foramen, it is joined by the cranial root of the accessory nerve.
5. Leaving the skull, the nerve descends within the carotid sheath, in between the internal jugular vein (laterally), and the internal and common carotid arteries (medially).
6. At the *root of the neck*, the right vagus enters the thorax by crossing the first part of the subclavian artery, and then inclining medially behind the brachiocephalic vessels, to reach the right side of the trachea. The left vagus enters the thorax by passing between the left common carotid and left subclavian arteries, behind the internal jugular and brachiocephalic veins.
7. Vagus bears two ganglia—superior and inferior. The *superior ganglion* is rounded and lies in the jugular foramen. It gives meningeal and auricular branches of vagus, and is connected to glossopharyngeal and accessory nerves and to superior cervical ganglion of sympathetic chain. The *inferior ganglion* is cylindrical (2.5 cm) and lies near the base of skull. It gives pharyngeal, carotid, superior laryngeal branches and is connected to hypoglossal nerve, superior cervical ganglion and the loop between first and second cervical nerves.

Cranial root of XI nerve joins vagus nerve at the inferior ganglion.

Branches in Head and Neck

The branches are listed in Table 6.4.

TABLE 6.4: Branches of vagus nerve

Region	*Branches*
A. In head and neck	
1. From the superior ganglion	• Meningeal branches: Sensory supply to dura mater of the posterior cranial fossa • Auricular branch (Arnold's nerve or Alderman's nerve): Supplies the posterior half of external auditory meatus, outer surface of the tympanic membranes, concha and root of the auricle
2. From inferior ganglion	• Pharyngeal branches: All the muscles of pharynx except stylopharyngeus which is supplied by the glossopharyngeal nerve. All the muscles of soft palate except the tensor veli palatini which is supplied by mandibular nerve • Carotid branches: Sensation from the carotid body and sinus • Superior laryngeal branch – external and internal laryngeal nerves. *Internal laryngeal nerve*: Sensation from mucous membranes of pharynx, epiglottis, vallecula and laryngeal vestibule, mucosa of pyriform fossa aryepiglottic folds, mucosa of larynx up to the vocal folds. *External laryngeal nerve*: Supplies cricothyroid and inferior constrictor of pharynx • Right recurrent laryngeal nerve: Supply—all the intrinsic muscles of larynx except cricothyroid which is supplied by the external laryngeal nerve and mucous membranes of larynx below the vocal folds • Superior and inferior carotid branches
B. In the thorax	
1. Left recurrent laryngeal nerve	• Cardiac, tracheal and oesophageal branches • To inferior constrictor • To all intrinsic muscle of larynx except cricothyroid • Sensory branch to mucous membrane of larynx below the vocal cords
2. Pulmonary branches	Supply the lungs through pulmonary plexuses
3. Carotid branch	Supply the carotid body and carotid sinus
4. Oesophageal branches	Supply oesophagus
5. Cardiac branches	Supply the heart through cardiac plexuses
C. In abdomen	
From anterior vagal trunk	1. Hepatic branch for liver, pylorus, duodenum, and pancreas 2. Upper gastric branches for anterior surface of body and fundus 3. Greater anterior gastric nerve – the main gastric branch, gives fibres to the body and antrum. It ends at incisura angularis in crow's foot pattern 4. Pyloric branch to supply pylorus
From posterior vagal trunk	1. Gastric branches for posterior surface of stomach except pylorus. Its major gastric branch is called greater posterior gastric nerve or posterior nerve of lesser curvature 2. Coeliac branch reaches the coeliac plexus via left gastric artery 3. Nerve of Grassi: For fundus of stomach

Note: The *right recurrent laryngeal nerve* arises from the vagus in front of the right subclavian artery, winds backwards below the artery, and runs upwards and medially behind the subclavian and common carotid arteries to reach the tracheo-oesophageal groove. In the upper part of the groove, it is intimately related to the inferior thyroid artery.

The *left recurrent laryngeal nerve* arises from the vagus in the thorax, as the latter crosses the left side of the arch of the aorta. It loops around the ligamentum arteriosum and reaches the tracheo-oesophageal groove. Its distribution is similar to that of the right nerve. It does not have to pass behind the subclavian and carotid arteries; and usually, it is posterior to the inferior thyroid artery.

CLINICAL NEUROANATOMY

- ***Clinical testing of vagus nerve***: The vagus nerve is tested clinically by comparing the palatal arches on the two sides. On the paralysed side, there is no arching, and the uvula is pulled to the normal side.
- ***Paralysis of the vagus nerve*** produces (Fig. 6.46):
  a. Nasal regurgitation of swallowed liquids
  b. Nasal twang in voice
  c. Hoarseness of voice
  d. Flattening of the palatal arch
  e. Cadaveric position of the vocal cord
  f. Dysphagia.
- ***Aldermen's nerve phenomenon***: Stimulation of auricular area supplied by vagus cause increased appetite. In the Alderman, in ancient Rome, used to stimulate the appetite by dropping cold water behind the ear. This stimulation causes reflex, increased gastric motility and acid secretion.
- ***Irritation of the auricular branch of the vagus*** in the external ear (by ear wax, syringing, etc.) may reflexly cause persistent cough (ear cough), vomiting, or even death due to sudden cardiac inhibition.
- Irritation of the recurrent laryngeal nerve by enlarged lymph nodes in children may also produce a persistent cough.

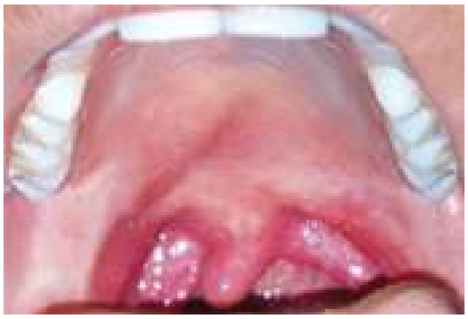


Fig. 6.46: Paralysis of muscles of soft palate on left side

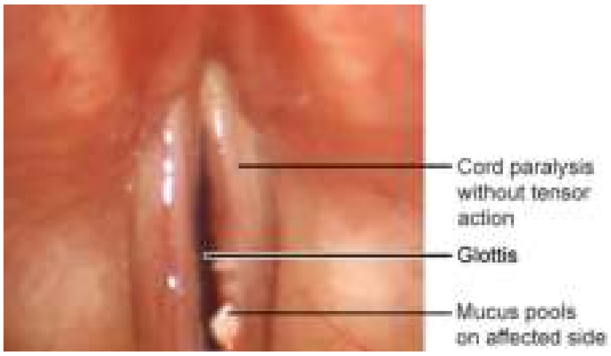

Cord paralysis without tensor action
Glottis
Mucus pools on affected side

Fig. 6.47: Injury to right recurrent laryngeal nerve

- Some fibres arising in the geniculate ganglion of facial nerve pass into the vagus through communications between the two nerves. They reach the skin of auricle through the auricular branch of vagus. Sometimes a sensory ganglion may have a viral infection (called herpes zoster) and vesicles appear on the area of skin supplied by the ganglion. In herpes zoster of the geniculate ganglion, vesicles appear on the skin of auricle.
- Injury to pharyngeal branch causes dysphagia. Paralysis of muscles of soft palate results in nasal regurgitation of fluids and nasal tone of voice. Lesions of superior laryngeal nerve produces anaesthesia in the upper part of larynx and paralysis of cricothyroid muscle. The voice is weak and gets tired easily.
- Injury to right recurrent laryngeal nerve results in hoarseness and dysphonia due to paralysis of the right vocal cord (Fig. 6.47).
- Paralysis of both vocal cords results in aphonia and inspiratory stridor (high-pitched and harsh respiratory sound). It may occur during thyroid surgery.
- During thyroidectomy, recurrent laryngeal nerve may be injured resulting in fixed and paramedian vocal cords.
- In severe peptic ulcer, ***vagotomy*** is done to relieve the symptoms.

ELEVENTH CRANIAL NERVE

(ACCESSORY NERVE)

Accessory nerve is the eleventh cranial nerve. It has two roots—cranial and spinal. The cranial root is assisting the vagus, and is distributed through its branches as vagoaccessory complex. The spinal root has a more independent course (Fig. 6.48 and Flowchart 6.16).

Functional Components

1. ***Special visceral efferent*** (*SVE*) *fibres*: They begins from *nucleus ambiguus*. These are motor fibres for the muscles of soft palate, pharynx, and larynx. They form the cranial root and get distributed through the branches of vagus nerve.
2. ***General somatic efferent*** (*GSE*) *fibres*: They begins from *spinal nucleus of accessory nerve* which extends in the anterior grey column of the spinal cord from C1 and C5 segments. These fibres supply sternocleidomastoid and trapezius.

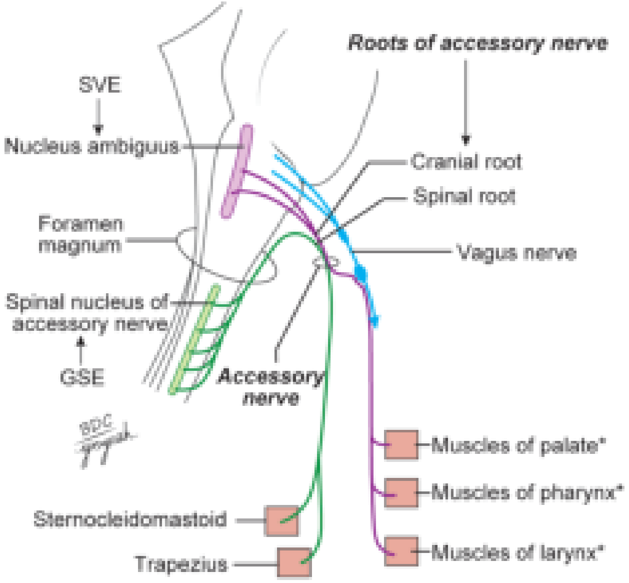
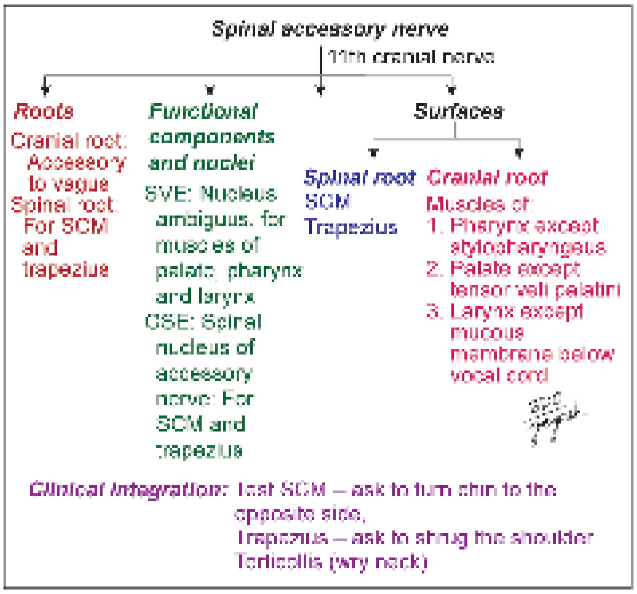

Roots of accessory nerve
SVE
Nucleus ambiguus
Cranial root
Spinal root
Foramen magnum
Vagus nerve
Spinal nucleus of accessory nerve
GSE
Accessory nerve
Muscles of palate*
Muscles of pharynx*
Sternocleidomastoid
Muscles of larynx*
Trapezius

Fig. 6.48: Course and distribution of the accessory nerve (SVE: Special visceral efferent, GSE: General somatic efferent, *: for details about exceptions, refer the text)

Flowchart 6.16: Spinal accessory nerve


Spinal accessory nerve
11th cranial nerve
Roots
Cranial root: Accessory to vagus
Spinal root: For SCM and trapezius
Functional components and nuclei
SVE: Nucleus ambiguus, for muscles of palate, pharynx and larynx
GSE: Spinal nucleus of accessory nerve: For SCM and trapezius
Surfaces
Spinal root
SCM
Trapezius
Cranial root
Muscles of:
1. Pharynx except stylopharyngeus
2. Palate except tensor veli palatini
3. Larynx except mucous membrane below vocal cord
Clinical Integration: Test SCM – ask to turn chin to the opposite side,
Trapezius – ask to shrug the shoulder
Torticollis (wry neck)

(SCM: Sternocleidomastoid, GSE: General somatic efferent, SVE: Special visceral efferent)

Origin of Accessory Nerve

1. *Cranial root*: It emerges as 4–5 rootlets from the posterolateral sulcus of the medulla. They join to from a single trunk.
2. *Spinal root*: It arises as a row of filaments from the upper 5 segments of spinal cord between the ventral and dorsal nerve roots. In the vertebral canal, the filaments unite to form a single trunk which ascend in front of the dorsal root and behind the ligamentum denticulatum.

Nuclei

1. The cranial root arises from the lower part of the *nucleus ambiguus*.
2. The spinal root arises from a long *spinal nucleus* situated on the lateral part of anterior grey column of spinal cord, extending from C1 to C5 segments. It is in line with nucleus ambiguus.

Course and Distribution of the Cranial Root (Fig. 6.48)

1. The cranial root emerges in the form of 4 to 5 rootlets which are attached to the posterolateral sulcus of the medulla. Just below, the rootlets soon join together to form a single trunk.
2. It runs laterally with the glossopharyngeal vagus and spinal accessory nerves, crosses the jugular tubercle, and reaches jugular foramen.
3. In the jugular foramen, the cranial root unites for a short distance with the spinal root, and again separates from spinal root as it passes out of the foramen.
4. The cranial root finally fuses with the vagus at its inferior ganglion, and is distributed through the branches of the vagus to the muscles of the palate, the pharynx, the larynx and possibly the heart.

Course and Distribution of the Spinal Root (Fig. 6.48)

1. It arises from the upper five segments of the spinal cord.
2. It emerges in the form of a row of filaments attached to the cord midway between the ventral and dorsal nerve roots.
3. *In the vertebral canal*, the filaments unite to form a single trunk which ascends in front of the dorsal nerve roots and behind the ligamentum denticulatum.
4. The nerve *enters the cranium* through the foramen magnum lying behind the vertebral artery.
5. Within the cranium, the nerve runs upwards and laterally, crosses the jugular tubercle (with the ninth and tenth cranial nerves) and reaches the jugular foramen.
6. The nerve *leaves the skull* through the middle part of the jugular foramen where it fuses with a short length of the cranial root. It soon separates from the latter and passes out of the foramen.
7. In its *extracranial course*, the nerve descends vertically between the internal jugular vein and the internal carotid artery deep to the parotid and to the styloid process. It reaches a point midway between the angle of mandible and the mastoid process. Then it runs downwards and backwards superficial to the internal jugular vein and is surrounded by lymph nodes.

   The nerve pierces the anterior border of the sternocleidomastoid at the junction of its upper one fourth with the lower three-fourths, and communicates with second and third cervical nerves within the muscle.

   The nerve enters the posterior triangle of the neck by emerging through the posterior border of the sternocleidomastoid a little above its middle. In the triangle, it runs downwards and backwards embedded in the fascial roof of the triangle. Here it lies over the levator scapulae. It is related to the superficial lymph nodes. The nerve leaves the posterior triangle by passing deep to the anterior border of the trapezius 5 cm above the clavicle.

   On the deep surface of the trapezius, the nerve communicates with spinal nerves C3 and C4, and ends by supplying the trapezius.
8. ***Distribution:*** The spinal accessory nerve supplies:
   a. The sternocleidomastoid—the chin turning muscle.
   b. The trapezius—the shrugging muscle.

Cervical nerves provide a proprioceptive sensations to these muscles.

CLINICAL NEUROANATOMY

- ***Clinical testing:*** The accessory nerve is tested clinically:
  a. By asking the patient to shrug his shoulders (trapezius) against resistance and comparing the power on the two sides.
  b. By asking the patient to turn the chin to the opposite side (sternocleidomastoid) against resistance and again comparing the power on the two sides.
- ***Paralysis of spinal accessory nerve***: Lesions of spinal root of accessory nerve cause drooping of the shoulder and inability to turn chin to opposite side.
- Irritation of the nerve during biopsy of enlarged caseous lymph nodes may produce ***torticollis*** or wry neck.
- Supranuclear connections act on the ipsilateral sternocleidomastoid and on the contralateral trapezius. This results in turning of the head away from relevant hemisphere during seizure.
- Spasmodic torticollis—irritation of the nerve resulting in clonic spasm of the sternocleidomastoid and trapezius muscles.

TWELFTH CRANIAL NERVE
(HYPOGLOSSAL NERVE)

Hypoglossal nerve is the twelfth cranial nerve. It supplies the muscles of the tongue (Figs 6.50, 6.51 and Flowchart 6.17).

Functional Components/Nuclear Columns

1. ***General somatic efferent*** *(GSE) fibres*: They arise from the *hypoglossal nucleus* and supply all the intrinsic and extrinsic muscles of tongue except palatoglossus.
2. ***General somatic afferent*** *(GSA) fibres*: They carry proprioceptive fibres from the muscles of tongue to the *mesencephalic nucleus of trigeminal nerve*.

Hypoglossal Nucleus

The hypoglossal nucleus, 2 cm long, lies in the floor of fourth ventricle beneath the hypoglossal triangle. It is divided into a part for genioglossus and a part for rest of the muscles (Fig. 6.49).

Nucleus for genioglossus muscle receives only contralateral corticonuclear fibres. Nucleus for rest of the lingual muscles receives both ipsilateral and contralateral corticonuclear fibres.

Origin of Hypoglossal Nerve

The hypoglossal nerve arises by 10–15 rootlets on the ventral aspect of the medulla from anterolateral sulcus between pyramid and olive.

Course and Relations

1. In their *intraneural course*, the fibres pass forwards lateral to the medial longitudinal bundle, medial lemniscus and pyramidal tract, and medial to the reticular formation and olivary nucleus.
2. The nerve is attached to the anterolateral sulcus of the medulla, between the pyramid and the olive, by 10 to 15 rootlets (Fig. 6.50).

The rootlets run laterally behind the vertebral artery, and join to form two bundles which pierce the dura mater separately near the hypoglossal canal.

The nerve leaves the skull through the hypoglossal (anterior condylar) canal.

Extracranial Course

1. The nerve first lies deep to the internal jugular vein, but soon inclines between the internal jugular vein and the internal carotid artery, crosses the vagus (laterally), and reaches in front of it.
2. It then descends between the internal jugular vein and the internal carotid artery in front of the vagus, deep to the parotid gland, the styloid process, the posterior belly of the digastric.
3. At the lower border of the posterior belly of the digastric, it curves forwards, crosses the internal and external carotid arteries and the loop of the lingual artery, and passes deep to the posterior belly of the digastric again to enter the submandibular region.
4. The nerve then continues forwards on the hyoglossus and genioglossus, deep to the submandibular gland and the mylohyoid, and enters the substance of the tongue to supply all its intrinsic muscles and most of its extrinsic muscles.

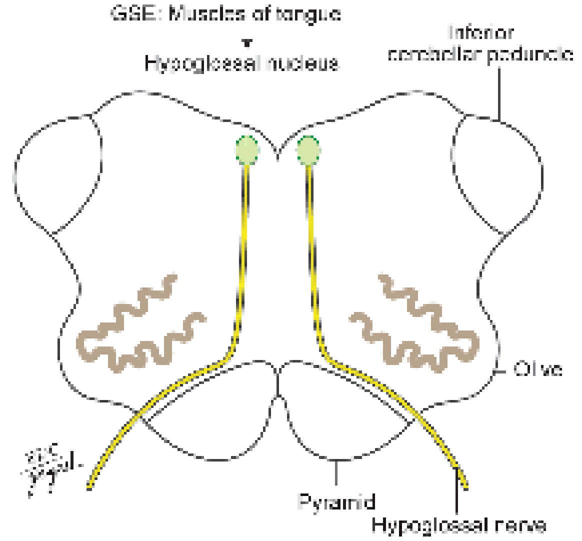

GSE: Muscles of tongue
Hypoglossal nucleus
Inferior cerebellar peduncle
Olive
Pyramid
Hypoglossal nerve

Fig. 6.49: Functional components and nucleus of the hypoglossal nerve (transverse section of the medulla oblongata)

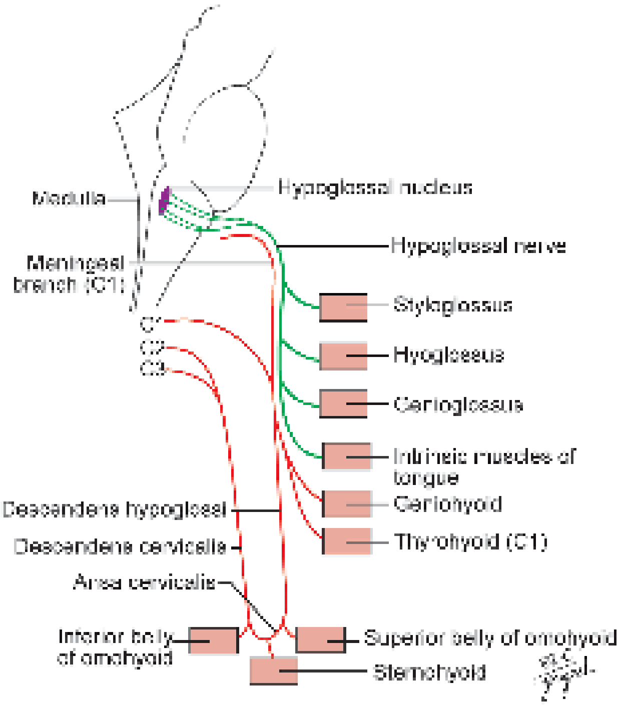
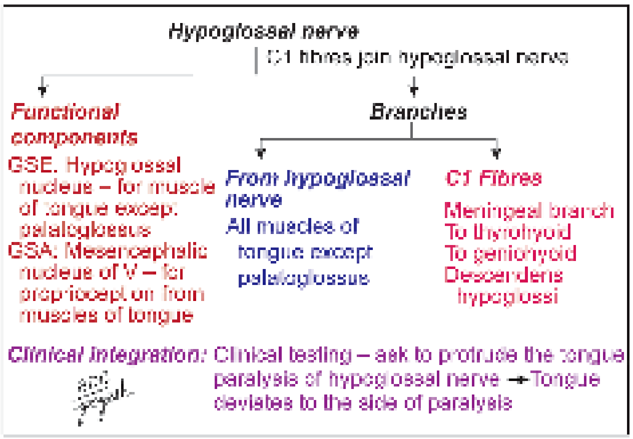

Medulla
Hypoglossal nucleus
Hypoglossal nerve
Meningeal branch (C1)
C1
C2
C3
Styloglossus
Hyoglossus
Genioglossus
Intrinsic muscles of tongue
Geniohyoid
Thyrohyoid (C1)
Descendens hypoglossi
Descendens cervicalis
Ansa cervicalis
Inferior belly of omohyoid
Superior belly of omohyoid
Sternohyoid

Fig. 6.50: Hypoglossal nerve

Flowchart 6.17: Hypoglossal nerve


Hypoglossal nerve
C1 fibres join hypoglossal nerve
Functional components
GSE. Hypoglossal nucleus – for muscle of tongue except palatoglossus
GSA: Mesencephalic nucleus of V – for proprioception from muscles of tongue
Branches
From hypoglossal nerve
All muscles of tongue except palatoglossus
C1 Fibres
Meningeal branch
To thyrohyoid
To geniohyoid
Descendens hypoglossi
Clinical integration: Clinical testing – ask to protrude the tongue
paralysis of hypoglossal nerve → Tongue deviates to the side of paralysis

(GSE: General somatic efferent, GSA: General somatic afferent)

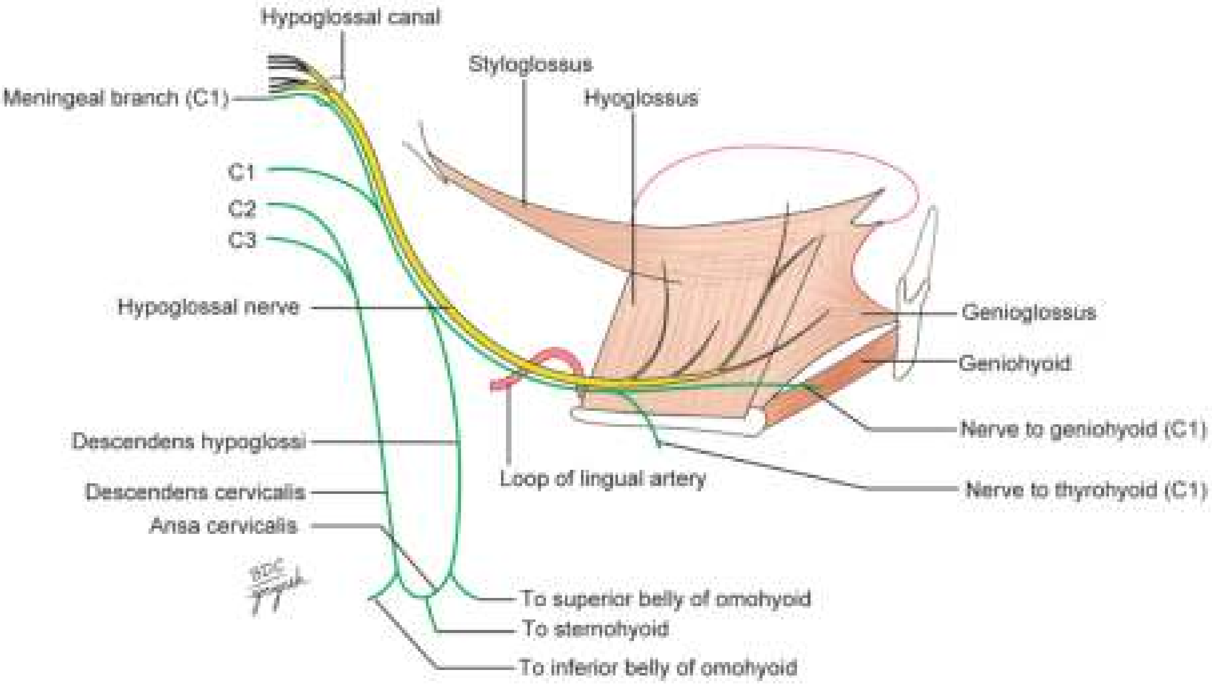

Hypoglossal canal
Styloglossus
Hyoglossus
Meningeal branch (C1)
C1
C2
C3
Hypoglossal nerve
Genioglossus
Geniohyoid
Nerve to geniohyoid (C1)
Nerve to thyrohyoid (C1)
Descendens hypoglossi
Descendens cervicalis
Ansa cervicalis
Loop of lingual artery
To superior belly of omohyoid
To sternohyoid
To inferior belly of omohyoid

Fig. 6.51: Hypoglossal nerve and ansa cervicalis

Branches and Distribution (Fig. 6.50 and 6.51)

Branches of Hypoglossal Nerve Proper

Branches to supply all the intrinsic and extrinsic muscles of tongue except palatoglossus which is supplied by cranial part of accessory nerve through the vagus nerve.

Branches of Hypoglossal Nerve Containing C1 Fibres

The hypoglossal nerve is joined by fibres of C1 spinal nerve. These fibres give following branches:

1. *Meningeal branches*: They enter the cranial cavity through the hypoglossal canal and supply the dura mater of the posterior cranial fossa.
2. Descends hypoglossi or the upper root of ansa cervicalis: It arises from the hypoglossal nerve in front of the internal carotid artery. It descends in the anterior wall of carotid sheath and joins to the inferior root of ansa cervicalis at the level of cricoid cartilage.
3. *Nerve to thyrohyoid*: It crosses the greater cornua of the hyoid bone and supplied thyrohyoid muscle.
4. *Nerve of geniohyoid*: It arises above the hyoid bone and supply the geniohyoid muscle.

CLINICAL NEUROANATOMY

- ***Clinical testing of hypoglossal nerve***: Ask the patient to protrude the tongue. Normally, the tongue is protruded forwards in the midline. If the hypoglossal nerve of one side is paralysed, the tongue deviates to the side of paralysis due to action of contralateral genioglossus muscle.
- If both the hypoglossal nerves are paralysed, the patient cannot protrude the tongue.

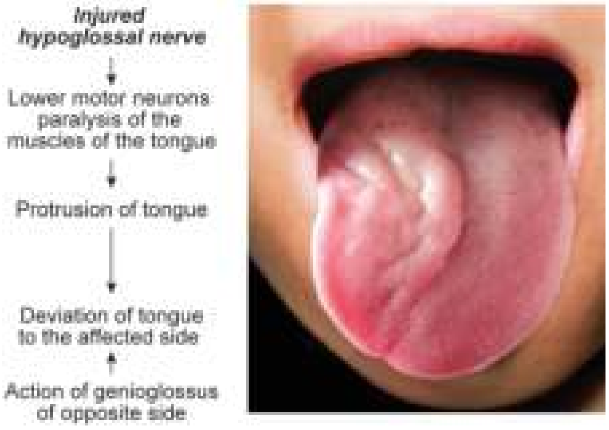

Injured hypoglossal nerve
Lower motor neurons paralysis of the muscles of the tongue
Protrusion of tongue
Deviation of tongue to the affected side
Action of genioglossus of opposite side

Fig. 6.52: XII nerve paralysis on right side

- ***Lesions of hypoglossal nerve***: The lesions of hypoglossal nerve are divided into intranuclear and supranuclear lesions.
  a. ***Intranuclear lesions*** or injury to the hypoglossal nerve: It results into the lower motor neuron type of paralysis of the muscles of the tongue on the side of lesion. On protrusion of tongue, it deviates to the affected side due to the action of genioglossus of opposite side (Fig. 6.52). In bilateral hypoglossal nerve injury, the patient cannot protrude the tongue. Speech and swallowing are affected.
  b. ***Supranuclear lesion*** of hypoglossal nerve: It occurs due to damage to the corticonuclear fibres connecting motor area of cerebrum to the hypoglossal nucleus. It results into upper motor neuron type of paralysis. On protrusion, the tongue deviates to the opposite side. The supranuclear lesion affects the muscles of opposite side of the tongue.

Facts to Remember

- III nerve carries parasympathetic fibres from Edinger-Westphal nucleus of midbrain to the ciliaris and constrictor pupillae muscles for accommodation.
- VII nerve carries parasympathetic fibres from lacrimatory nucleus to pterygopalatine ganglion for the lacrimal gland and glands in nasal cavity, palate and pharynx.
- VII nerve also carries parasympathetic fibres from superior salivatory nucleus to submandibular ganglion for the supply of submandibular, sublingual glands and glands in the oral cavity.
- IX nerve carries parasympathetic fibres from inferior salivatory nucleus to the otic ganglion for the supply of parotid gland.
- X nerve carries parasympathetic fibres from dorsal nucleus of vagus for the glands in the respiratory tract and glands in the digestive tract till right two-thirds of the transverse colon.
- Only trochlear nerve emerges on the dorsal aspect of the brainstem.
- V, VII, IX nerves are the nerves of 1st, 2nd, 3rd arches, respectively.
- X, XI, i.e. vagoaccessory complex supplies structures developed from 4th and 6th branchial arches.

BDC's Anatomy e-book

1. Nuclei of the cranial nerves
2. Highlights of the cranial nerves
3. Oculomotor nuclear complex
4. Sensory and motor components of V nerve
5. Foramina for cranial nerves and their branches
6. Further reading
7. Viva voce questions

Chapter 7

Brainstem

The brainstem is a connecting stalk between the spinal cord and cerebrum. It consists of three parts (Plates 7.1 and 7.2, Figs 7.1 to 7.3):

1. Medulla oblongata
2. Pons
3. Midbrain.

The brainstem is located in the posterior cranial fossa. It lies on the sloping clivus.

It contains:

1. Ascending and descending pathways that connect cerebrum, cerebellum, and spinal cord with each other
2. Reticular formation
3. Cranial nerve nuclei and their origin (IIIrd to XIIth)
4. Vital centres that control heart rate, blood pressure and respiration.

Note: Damage to vital centres leads to death due to respiratory and cardiac failures. A damage to ascending reticular system may lead to loss of consciousness or coma.

The gross specimens showing the transverse sections (TS) of medulla oblongata, pons, midbrain, and the spinal cord at various levels are shown in Plate 7.2 for comparison.

Competency:
AN58.1 Identify external features of medulla oblongata.

MEDULLA OBLONGATA

The medulla is the lowest part of brainstem (Plate 7.1, Fig. 7.1, Flowchart 7.1).

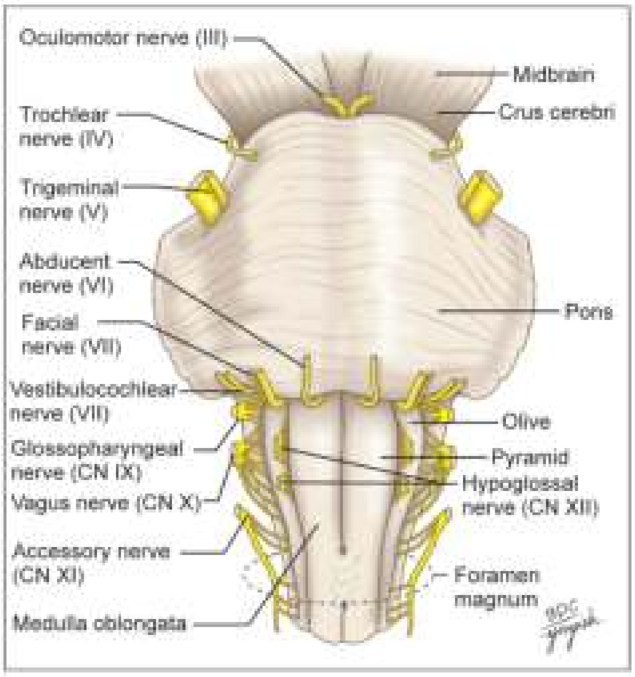
Extent

The medulla extends from the lower border of pons to a plane just above which the 1st cervical nerve arises where it is continuous with the spinal cord. It lies in the anterior part of posterior cranial fossa, extending down to the foramen magnum.

Relations

Anteriorly, it is related to the clivus and meninges and posteriorly, to the vallecula of the cerebellum. Along with other parts of the hindbrain, medulla occupies the infratentorial space.

Plate 7.1: Brainstem (anterior view)


Oculomotor nerve (III)
Midbrain
Trochlear nerve (IV)
Crus cerebri
Trigeminal nerve (V)
Abducent nerve (VI)
Pons
Facial nerve (VII)
Vestibulocochlear nerve (VII)
Olive
Glossopharyngeal nerve (CN IX)
Pyramid
Hypoglossal nerve (CN XII)
Vagus nerve (CN X)
Accessory nerve (CN XI)
Foramen magnum
Medulla oblongata

Parts

1. *Open/superior part*—the dorsal surface of the medulla is formed by the fourth ventricle.
2. *Closed/inferior part*—fourth ventricle is narrowed at the obex and continues with the central canal.

Measurements

Length: 3 cm

Width: 2 cm at its widest part

Thickness: 1.25 cm.

EXTERNAL FEATURES

1. ***Fissures and sulci:*** The medulla is divided into right and left halves by the ***anterior and posterior median fissures***. The anterior median fissure ends in ***foramen caecum*** at its junction with pons. Each half is further divided into anterior, lateral and posterior regions by the ***anterolateral and posterolateral sulci*** (Plate 7.1, Fig. 7.1, Flowchart 7.1).

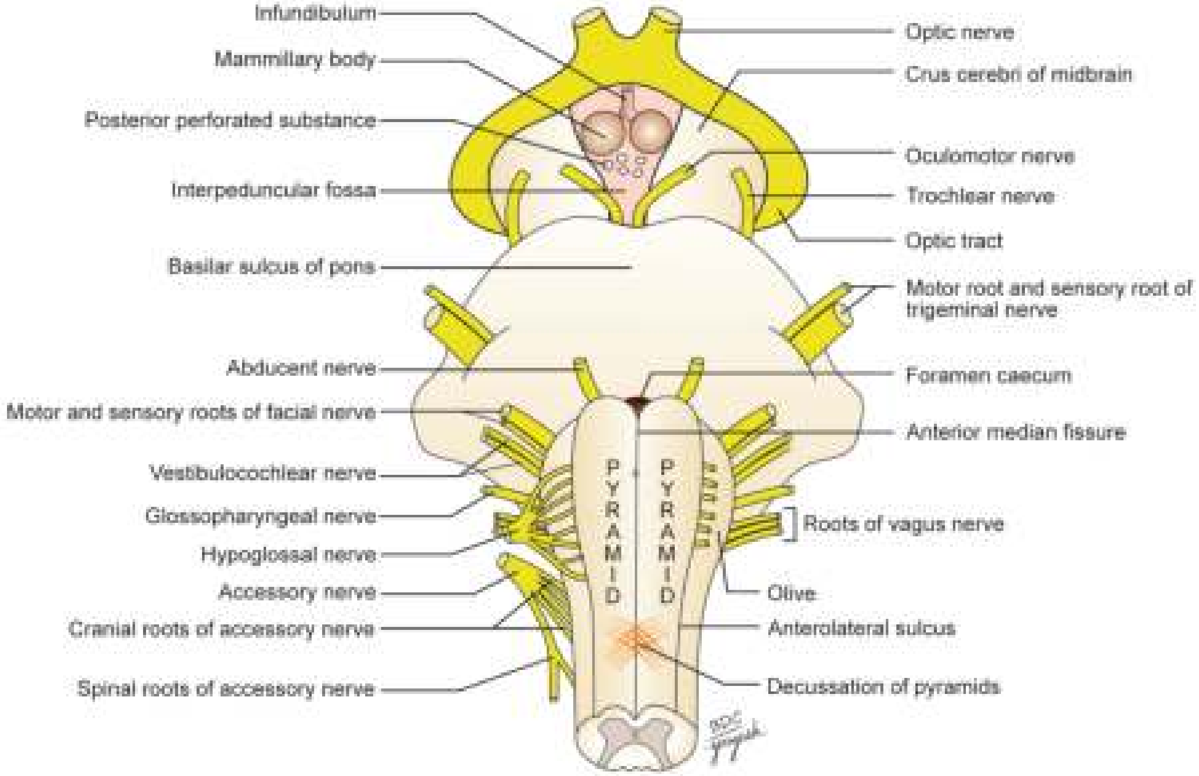

Infundibulum
Mammillary body
Posterior perforated substance
Interpeduncular fossa
Basilar sulcus of pons
Abducent nerve
Motor and sensory roots of facial nerve
Vestibulocochlear nerve
Glossopharyngeal nerve
Hypoglossal nerve
Accessory nerve
Cranial roots of accessory nerve
Spinal roots of accessory nerve
Optic nerve
Crus cerebri of midbrain
Oculomotor nerve
Trochlear nerve
Optic tract
Motor root and sensory root of trigeminal nerve
Foramen caecum
Anterior median fissure
Roots of vagus nerve
Olive
Anterolateral sulcus
Decussation of pyramids
PYRAMID
PYRAMID

Fig. 7.1: Attachment of cranial nerves to the ventral surface of brainstem

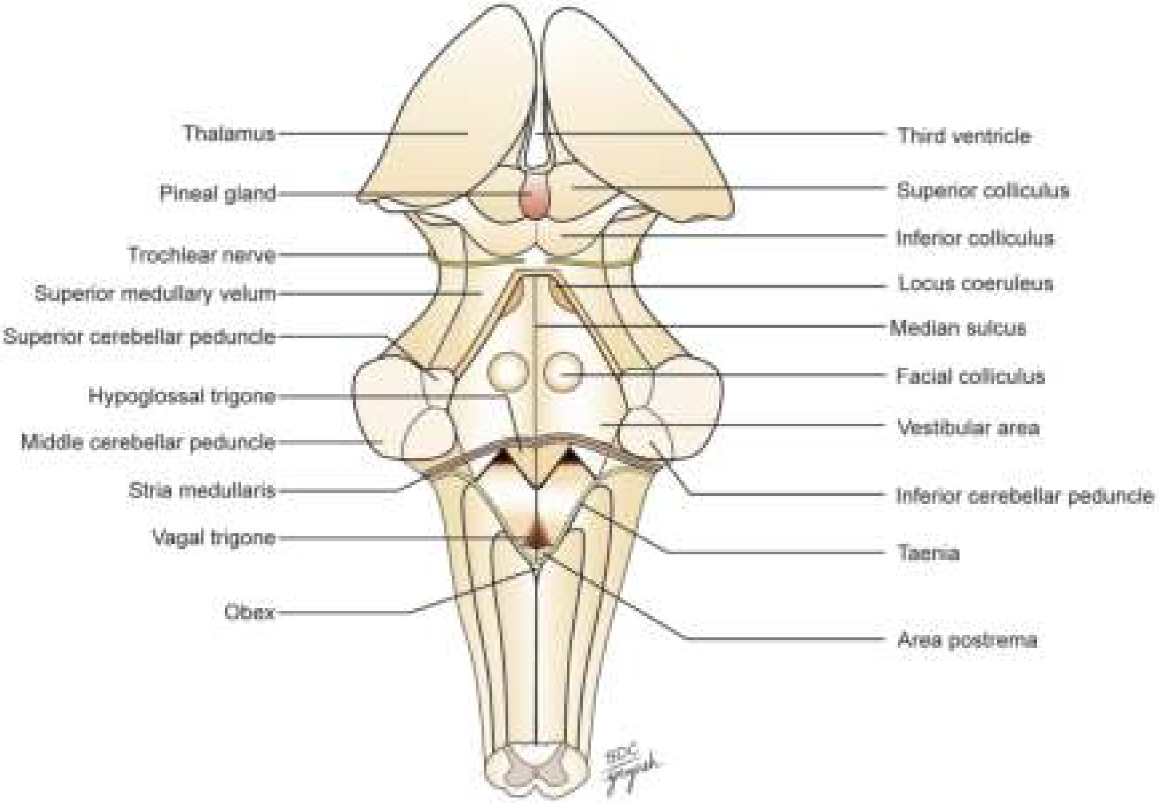
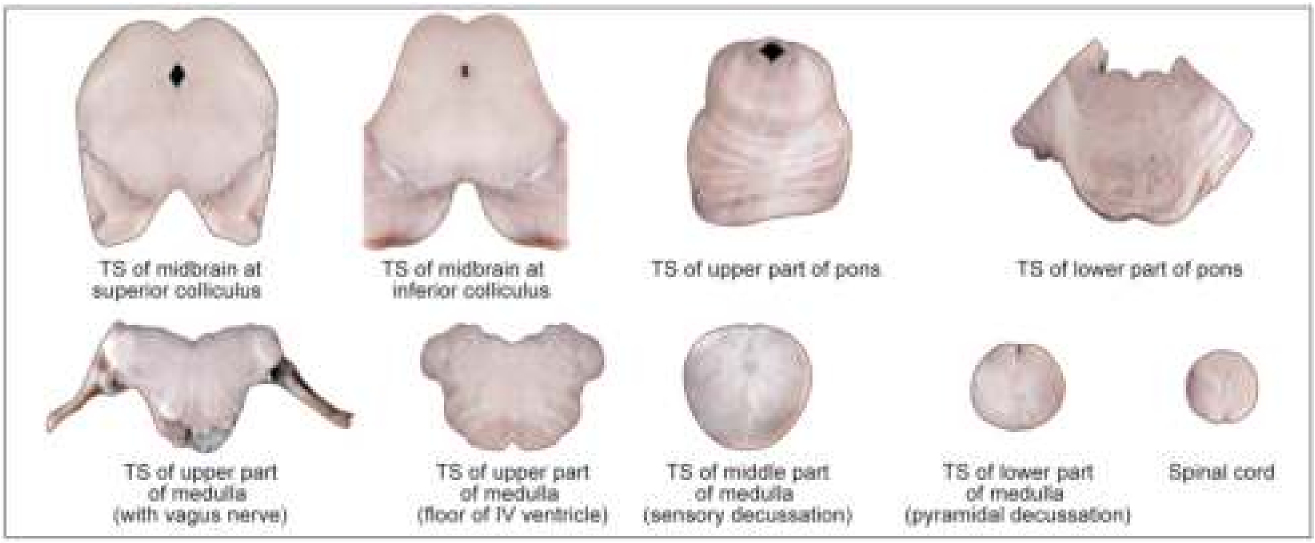

Thalamus
Pineal gland
Trochlear nerve
Superior medullary velum
Superior cerebellar peduncle
Hypoglossal trigone
Middle cerebellar peduncle
Stria medullaris
Vagal trigone
Obex
Third ventricle
Superior colliculus
Inferior colliculus
Locus coeruleus
Median sulcus
Facial colliculus
Vestibular area
Inferior cerebellar peduncle
Taenia
Area postrema

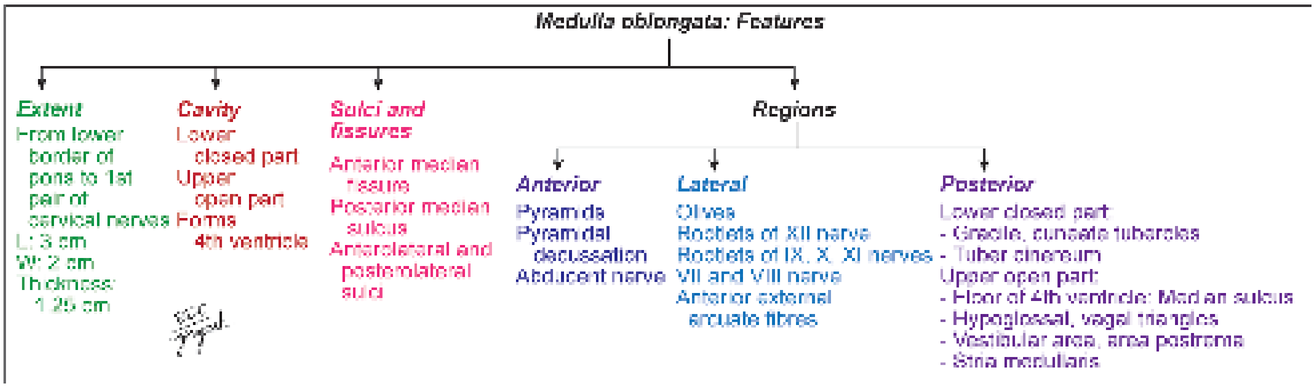
Fig. 7.2: Dorsal aspect of brainstem

2. ***Anterior region:*** The *anterior region* on either side of the fissure is formed of a longitudinal elevation called the ***pyramid***. The pyramid is made up of corticospinal and corticobulbar fibres. In the lower part of the medulla, many fibres of the right and left pyramids cross in the midline forming the ***pyramidal decussation***.

Plate: 7.2: Gross specimens showing the transverse sections (TS) of medulla oblongata, pons, midbrain, and the spinal cord at various levels


TS of midbrain at superior colliculus
TS of midbrain at inferior colliculus
TS of upper part of pons
TS of lower part of pons
TS of upper part of medulla (with vagus nerve)
TS of upper part of medulla (floor of IV ventricle)
TS of middle part of medulla (sensory decussation)
TS of lower part of medulla (pyramidal decussation)
Spinal cord

Flowchart 7.1: Medulla oblongata: Features


Medulla oblongata: Features
Extent
From lower border of pons to 1st pair of cervical nerves
L: 3 cm
W: 2 cm
Thickness: 1.25 cm
Cavity
Lower closed part
Upper open part
Forms 4th ventricle
Sulci and fissures
Anterior median fissure
Posterior median sulcus
Anterolateral and posterolateral sulci
Regions
Anterior
Pyramids
Pyramidal decussation
Abducent nerve
Lateral
Olives
Rootlets of XII nerve
Rootlets of IX, X, XI nerves
VII and VIII nerve
Anterior external arcuate fibres
Posterior
Lower closed part
- Gracile, cuneate tubercles
- Tuber cinereum
Upper open part
- Floor of 4th ventricle: Median sulcus
- Hypoglossal, vagal triangles
- Vestibular area, area postrema
- Stria medullaris

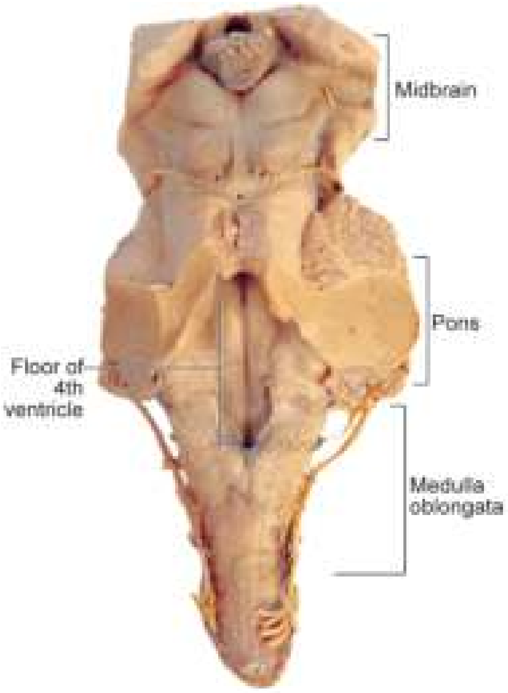

Midbrain
Pons
Floor of 4th ventricle
Medulla oblongata

Fig. 7.3: Gross anatomy of brainstem – Dorsal view

Some fibres run transversely across the upper part of the pyramid. These are the ***anterior external arcuate fibres*** which end in the cerebellum.

3. ***Lateral region:*** The upper part of the lateral region shows an oval elevation—the ***olive***. It is produced by an underlying mass of grey matter called the *inferior olivary nucleus*.

   The rootlets of the ***hypoglossal nerve*** emerge from the anterolateral sulcus between the pyramid and the olive.

   The rootlets of the cranial nerves *IX, X and cranial part of the accessory nerve* emerge through the posterolateral fissure, behind the olive.
4. ***Posterior region:*** The posterior region lies between the posterolateral sulcus and the posterior median fissure. The upper part of this region is marked by a V-shaped depression which is the lower part of the *floor of the fourth ventricle*.

   Below the floor, there are three longitudinal elevations. From medial to lateral side, these are the fasciculus gracilis, the fasciculus cuneatus and the inferior cerebellar peduncle.

   The upper ends of fasciculus gracilis and cuneatus expand to form the ***gracile and cuneate tubercles***. These tubercles are formed by underlying masses of grey matter called the *nucleus gracilis* and *nucleus cuneatus*.

Lateral to cuneate nucleus is an accessory cuneate nucleus. Here the unconscious proprioceptive fibres of upper limb relay to terminate in the cerebellum via inferior cerebellar peduncle. This nucleus is equivalent to Clarke's column of spinal cord. These convey discriminative touch, pressure and senses of vibration, position and movements from ipsilateral part of the body. The fasciculus gracilis contains fibres from lower limb and lower part of the trunk, the fasciculus cuneatus from the upper limb and upper part of the trunk.

In the lower part of the medulla, there is another elevation the ***tuber cinerium*** lateral to the fasciculus cuneatus. It is produced by a mass of grey matter called the *spinal nucleus of the trigeminal nerve.*

Competencies:

AN58.2 Describe transverse section of medulla oblongata at the level of: (1) pyramidal decussation, (2) sensory decussation, (3) inferior olivary nucleus.

AN58.3 Enumerate cranial nerve nuclei in medulla oblongata with their functional group.

INTERNAL STRUCTURE

The internal structure (transverse section) of the medulla oblongata is studied at three levels (Plate 7.2):

1. At the lower closed part, that is, at the level of pyramidal decussation.
2. At the upper closed part – at the level of sensory decussation.
3. At the level of olives – open part of medulla.

Transverse Section through the Lower Part of the Medulla Passing through the Pyramidal Decussation

It resembles a transverse section of the spinal cord in having the same three funiculi and the same tracts (Flowchart 7.2 and Fig. 7.4).

Flowchart 7.2: Transverse sections (TS) of the medulla

TS of medulla at the level of pyramidal decussation

Grey matter
- Central grey matter with central canal
- Spinal nucleus of accessory nerve
- Nucleus gracilis and nucleus cuneatus
- Nucleus of spinal tract of trigeminal nerve
- Supraspinal nucleus (C1)

White matter
- Pyramid
- Decussation of pyramidal fibres
- Fasciculus gracilis and fasciculus cuneatus
- Spinal tract of trigeminal nerve
- Anterior and posterior spinocerebellar tract

TS of medulla at the level of sensory decussation

Grey matter
- Nucleus gracilis and nucleus cuneatus
- Nucleus of spinal tract of trigeminal nerve
- Accessory cuneate nu.
- Central grey matter:
  - Hypoglossal nucleus
  - Dorsal nucleus of vagus
  - Nucleus tractus solitarius
  - Inferior olivary nucleus

White matter
- Sensory decussation
- Pyramid
- Medial lemniscus
- Medial longitudinal bundle
- Spinal tract of trigeminal nerve
- Reticular formation
- Anterior and posterior spinocerebellar tracts
- Lateral and anterior spinothalamic tracts

TS of medulla at the level of olives (open part)

Grey matter
- Hypoglossal nucleus
- Dorsal nucleus of vagus
- Nucleus tracts solitarius
- Inferior and medial vestibular nuclei
- Nucleus ambiguus
- Dorsal and ventral cochlear nucleus
- Nucleus of spinal tract trigeminal nucleus
- Arcuate nuclei
- Inferior olivary nucleus

White matter
- Inferior cerebellar peduncle
- Olivocerebellar fibre
- Stria medullaris or external arcuate fibres
- Fibers of IXth, Xth, and XIth cranial nerves
- Pyramidal fibres

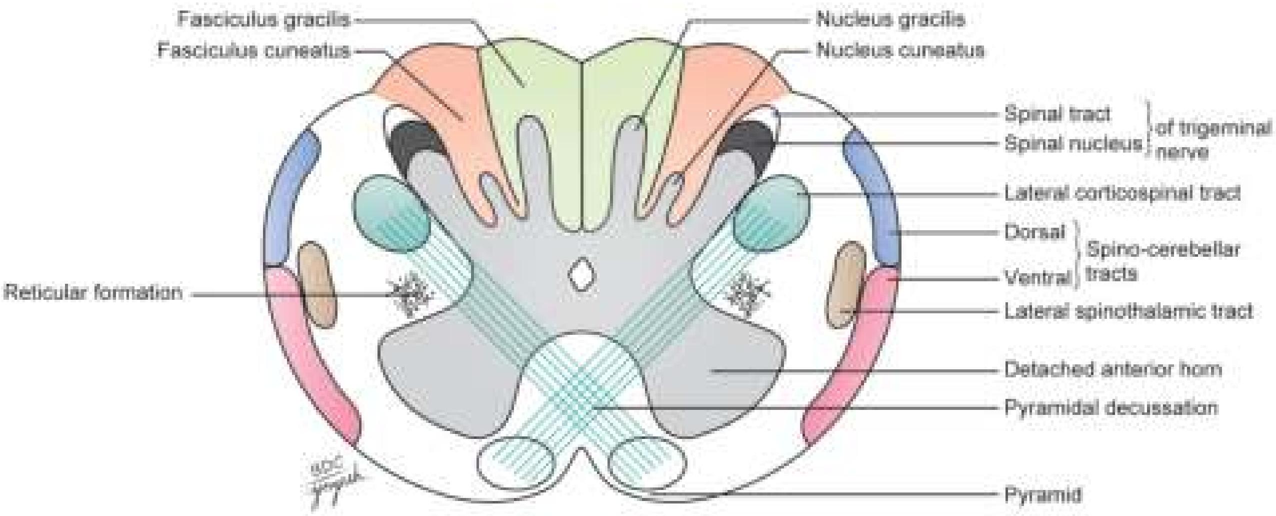


Fig. 7.4: Transverse section (TS) of medulla oblongata at the level of pyramidal decussation

Grey Matter

1. The decussating pyramidal fibres separate the anterior horn from the central grey matter. The *separated anterior horn* forms the *spinal nucleus of the accessory nerve* laterally and the ***supraspinal nucleus*** for motor fibres of the first cervical nerve medially.
2. The central grey matter (with the central canal) is pushed backwards.
3. The *nucleus gracilis* and the *nucleus cuneatus* are continuous with the central grey matter.
4. Laterally, the central grey matter is continuous with the nucleus of the *spinal tract of the trigeminal nerve*. A bundle of fibres overlying this nucleus forms the spinal tract of the trigeminal nerve.
5. *Reticular formation* made up of neurons and nerve fibres also present.

White Matter

1. The *pyramids*, anteriorly.
2. The *decussation* of the pyramidal tracts forms the most important features of the medulla at this level. The fibres of each pyramid run backwards and laterally to reach the lateral white column of the spinal cord where they form the *lateral corticospinal tract*.
3. The fasciculus gracilis and the fasciculus cuneatus occupy the broad posterior white column.
4. The other features of the white matter are similar to those of the spinal cord.

Transverse Section through the Middle of Medulla Passing through the Sensory Decussation

(Fig. 7.5 and Flowchart 7.2)

Grey Matter

1. The *nucleus gracilis* and *nucleus cuneatus* increase in size. They get separated from the central grey matter. The fibers of fasciculus gracilis and fasciculus cuneatus (which carries sensation of conscious proprioception, discrimination touch, and vibration) relay in nucleus gracilis and nucleus cuneatus.
2. Lateral to the cuneate nucleus, the ***accessory cuneate nucleus*** is present which relays unconscious proprioceptive fibres from the upper limbs. It is equivalent to nucleus dorsalis/Clarke's column.
3. The ***nucleus of the spinal tract of the trigeminal nerve*** is also separate from the central grey matter.
4. The lower part of the ***inferior olivary nucleus*** is seen.
5. The ***central grey matter*** contains the following:
    - Hypoglossal nucleus—an elongated nucleus about 2 cm long, supplies muscles of tongue except palatoglossus.
    - Dorsal nucleus of the vagus—gives preganglionic parasympathetic fibres to heart and to smooth muscles and glands of respiratory and alimentary system.
    - Nucleus of tractus solitarius—receives taste fibres.
6. Reticular formation made up of neurons and nerve fibres also present.

White Matter

1. The nucleus gracilis and cuneatus give rise to the ***internal arcuate fibres***. These fibres cross to the opposite side where they form a paramedian band of fibres, called the ***medial lemniscus***. In the lemniscus, the body is represented with the head posteriorly and the feet anteriorly.
2. The ***pyramid*** lie anteriorly.
3. The ***medial longitudinal bundle*** lies posterior to the medial lemniscus.
4. The *spinocerebellar, lateral spinothalamic* and other tracts lie in the anterolateral area.
5. Emerging fibres of XII nerve.

Transverse Section through the Upper Part of Medulla Passing through the Floor of Fourth Ventricle/Open Part (Fig. 7.6 and Flowchart 7.2)

Grey Matter

1. The nuclei of several cranial nerves are seen in the floor of the fourth ventricle:
    a. *Hypoglossal nucleus*, in a paramedian position.
    b. *Dorsal nucleus of the vagus*, lateral to the XII nerve nucleus.
    c. *Nucleus of the tractus solitarius*, ventrolateral to the dorsal nucleus of vagus.
    d. *Inferior and medial vestibular nuclei*, medial to the inferior cerebellar peduncle.
2. The *nucleus ambiguus* lies deep in the reticular formation of the medulla. It gives origin to motor fibres of the cranial nerves IX, X and XI.
3. The *dorsal and ventral cochlear nuclei* lie on the surface of the inferior cerebellar peduncle. These nuclei receive fibres of the cochlear nerve.
4. The *nucleus of the spinal tract* of the trigeminal nerve lies in the dorsolateral part.
5. The *arcuate nucleus* lies anteromedial to the pyramidal tract.
6. The *inferior olivary nucleus* is the largest mass of grey matter seen at this level. It is responsible for producing the elevation of the olive. Its grey matter appears like a crumpled purse. Close to the inferior olivary nucleus, there are the medial and dorsal accessory olivary nuclei. The nucleus receives the afferent fibres from cerebral cortex, red nucleus, periaqueductal grey of midbrain and spinal cord. The efferents form olivocerebellar fibres which terminate as climbing fibres at the cerebellar cortex.

Note: The visceral centres are placed deeply. These are:

a. Respiratory centre
b. Cardiac centre for regulation of heart rate
c. Vasomotor centre for regulation of blood pressure.
d. Reflex centres for vomiting coughing, sneezing, hiccuping and swallowing.

White Matter

It shows the following important features:

1. The *inferior cerebellar peduncle* occupies the posterolateral part, lateral to the fourth ventricle.

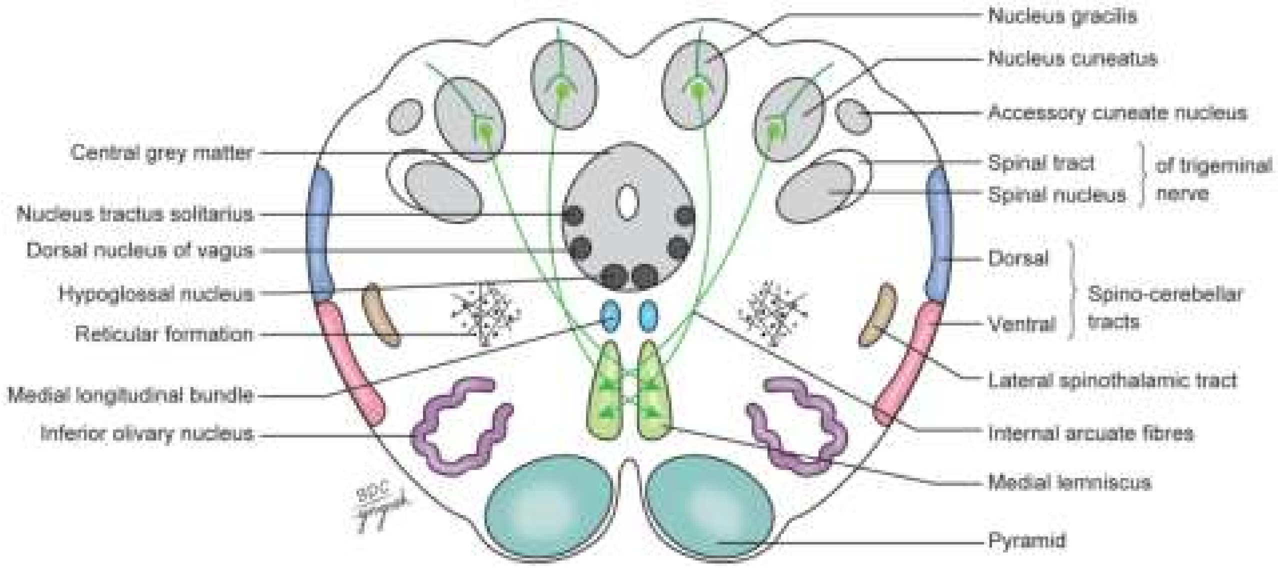

Nucleus gracilis
Nucleus cuneatus
Accessory cuneate nucleus
Central grey matter
Spinal tract
Spinal nucleus
of trigeminal nerve
Nucleus tractus solitarius
Dorsal nucleus of vagus
Dorsal
Hypoglossal nucleus
Ventral
Spino-cerebellar tracts
Reticular formation
Lateral spinothalamic tract
Medial longitudinal bundle
Inferior olivary nucleus
Internal arcuate fibres
Medial lemniscus
Pyramid
BDC

Fig. 7.5: Transverse section (TS) of medulla oblongata at the level of sensory decussation

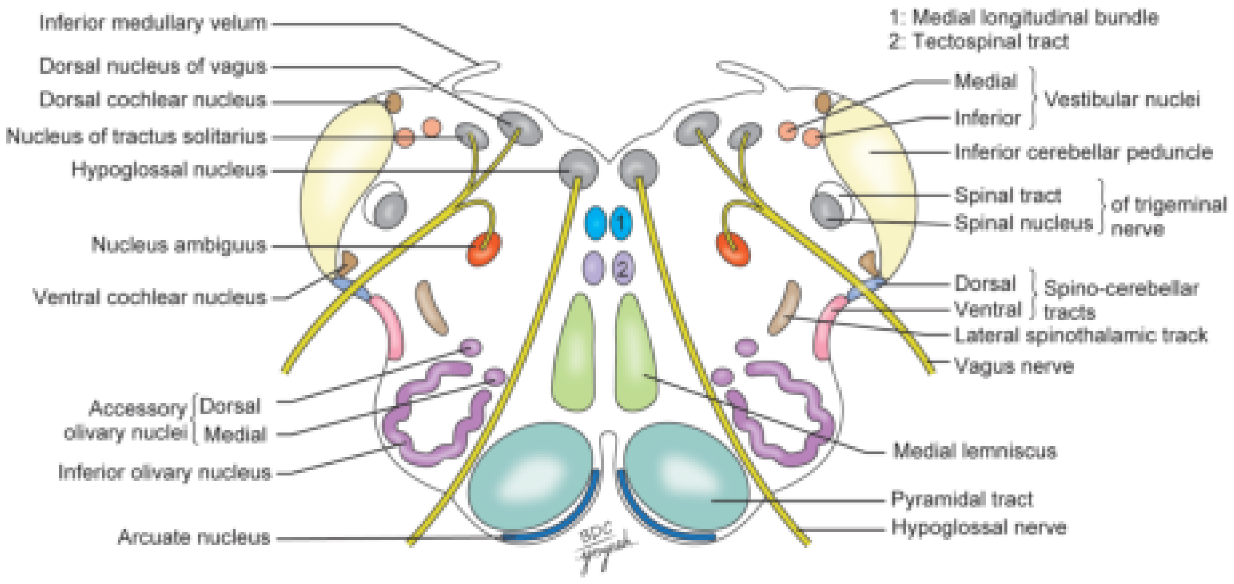

Inferior medullary velum
1: Medial longitudinal bundle
2: Tectospinal tract
Dorsal nucleus of vagus
Medial
Dorsal cochlear nucleus
Vestibular nuclei
Inferior
Nucleus of tractus solitarius
Inferior cerebellar peduncle
Hypoglossal nucleus
Spinal tract
Spinal nucleus
of trigeminal nerve
Nucleus ambiguus
1
2
Ventral cochlear nucleus
Dorsal
Ventral
Spino-cerebellar tracts
Lateral spinothalamic track
Vagus nerve
Accessory olivary nuclei
Dorsal
Medial
Medial lemniscus
Inferior olivary nucleus
Pyramidal tract
Arcuate nucleus
Hypoglossal nerve
BDC

Fig. 7.6: TS of medulla oblongata at the level of olivary nucleus passing through floor of fourth ventricle

2. The *olivocerebellar fibres* are seen prominently in actual sections. The fibres emerge at the hilum of the inferior olivary nucleus and pass to the opposite inferior cerebellar peduncle, on their way to the opposite half of the cerebellum.
3. *Striae medullaris (external arcuate fibres)* are seen in the floor of the fourth ventricle.
4. Emerging fibres of IX, X, XI nerves.
5. Various ascending and descending tracts.

BLOOD SUPPLY

- *Anterior spinal artery*: This supplies the whole medial part of the medulla oblongata.
- *Posterior inferior cerebellar artery*: This supplies the posterolateral part of the medulla.

Competency:

AN58.4 Describe the anatomical basis of clinical conditions affecting the medulla oblongata (medial and lateral medullary syndromes, crossed diplegia).

CLINICAL NEUROANATOMY

Medial medullary/Dejerine syndrome/Crossed diplegia: It occurs due to blockage of anterior spinal artery. Features are:

a. Contralateral hemiplegia (Fig. 7.3, Flowchart 7.3) due to damage to pyramid of medulla.
b. Loss of sense of vibration and position due to damage to medial lemniscus.
c. Paralysis of muscles of tongue on the same side due to injury to XII cranial nerve.

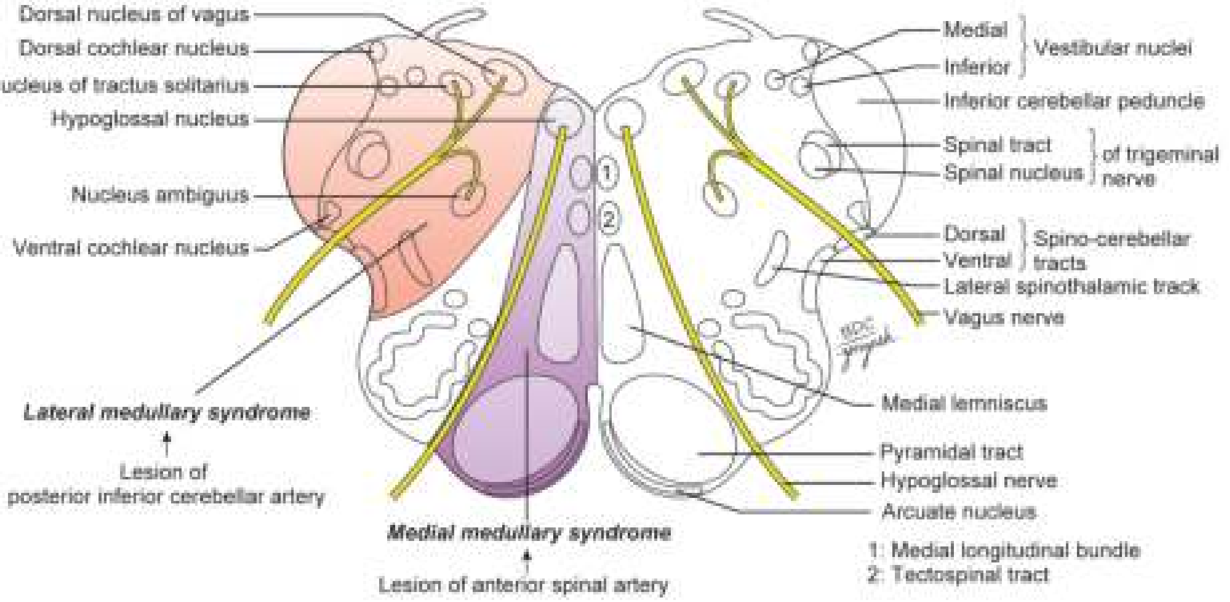

Dorsal nucleus of vagus
Dorsal cochlear nucleus
Nucleus of tractus solitarius
Hypoglossal nucleus
Nucleus ambiguus
Ventral cochlear nucleus
Lateral medullary syndrome
Lesion of
posterior inferior cerebellar artery
Medial medullary syndrome
Lesion of anterior spinal artery
Medial
Inferior
Vestibular nuclei
Inferior cerebellar peduncle
Spinal tract
Spinal nucleus
of trigeminal nerve
Dorsal
Ventral
Spino-cerebellar tracts
Lateral spinothalamic track
Vagus nerve
Medial lemniscus
Pyramidal tract
Hypoglossal nerve
Arcuate nucleus
1: Medial longitudinal bundle
2: Tectospinal tract
1
2

Fig. 7.7: Lesions of medulla oblongata: Light red coloured zone indicates the territory involved in lateral medullary syndrome and purple coloured zone indicates the territory involved in medial medullary syndrome (TS of medulla at the level of olives)

Lateral medullary/Wallenberg syndrome: Occurs due to blockage of posterior inferior cerebellar artery. It supplies areas behind the inferior olivary nucleus. Features are:

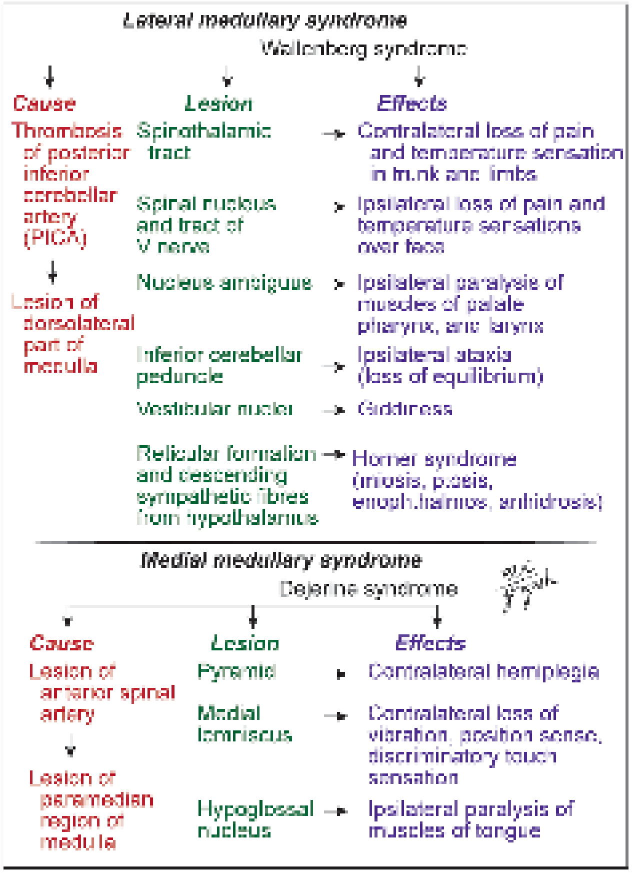
a. Ipsilateral paralysis of most of muscles of soft palate, pharynx and larynx due to injury to nucleus ambiguus which gives fibres to IX, X and XI cranial nerves (Fig. 7.7 and Flowchart 7.3).
b. Loss of pain and temperature on same side of face due to involvement of spinal nucleus and spinal tract of trigeminal nerve.
c. Loss of pain and temperature on opposite side of the body due to involvement of lateral spinothalamic tract.
d. Giddiness due to involvement of vestibular nuclei.
e. Damage to inferior cerebellar peduncle, spinocerebellar tracts and part of cerebellum results in loss of equilibrium, i.e. ataxia of limbs on the same side.
f. The sympathetic fibres descend from hypothalamus to cells in lateral horn of spinal cord. As these fibres descend in the lateral part of medulla (which is damaged), there is Horner's syndrome, comprising ptosis, enophthalmos, miosis and anhidrosis.

Injury to lower part of medulla oblongata: Injury in this part may be fatal due to injury to the vital centres, like respiratory centre and vasomotor centre.

Bulbar palsy: In this condition, there is weakness of muscles supplied by VII–XII cranial nerves. These nerves supply muscles of facial expression, muscles of pharynx, tongue, palate and larynx. The lesion is of lower motor neuron type. The patient has difficulty in speaking, swallowing and in usage of muscles of facial expression.

Pseudobulbar palsy: It occurs due to bilateral lesion of corticonuclear fibres. There is paralysis of muscles of tongue, lips, pharynx and palate. The causes of pseudobulbar palsy may be vascular infarction, syringomyelia and increased intracranial pressure.

Flowchart 7.3: Lateral and medial medullary syndromes


Lateral medullary syndrome
Wallenberg syndrome
Cause
Lesion
Effects
Thrombosis of posterior inferior cerebellar artery (PICA)
Lesion of dorsolateral part of medulla
Spinothalamic tract
Contralateral loss of pain and temperature sensation in trunk and limbs
Spinal nucleus and tract of V nerve
Ipsilateral loss of pain and temperature sensations over face
Nucleus ambiguus
Ipsilateral paralysis of muscles of palate pharynx, and larynx
Inferior cerebellar peduncle
Ipsilateral ataxia (loss of equilibrium)
Vestibular nuclei
Giddiness
Reticular formation and descending sympathetic fibres from hypothalamus
Horner syndrome (miosis, ptosis, enophthalmos, anhidrosis)
Medial medullary syndrome
Dejerine syndrome
Cause
Lesion
Effects
Lesion of anterior spinal artery
Lesion of paramedian region of medulla
Pyramid
Contralateral hemiplegia
Medial lemniscus
Contralateral loss of vibration, position sense, discriminatory touch sensation
Hypoglossal nucleus
Ipsilateral paralysis of muscles of tongue

PONS

The pons (Latin *bridge*) is also called metencephalon, 2.5 cm long and extends from cranial end of medulla oblongata to the cerebral peduncles of midbrain. Cranial nerves V, VI, VII, and VIII are attached here. Anteriorly, it is related to clivus separated by basilar artery, laterally to middle cerebellar peduncle and posteriorly to the fourth ventricle.

Competency:
AN59.1 Identify external features of pons.

EXTERNAL FEATURES

Surfaces

The pons has *two surfaces*—ventral and dorsal (Figs 7.1 and 7.2, Flowchart 7.4).

Ventral or Anterior Surface

1. The *ventral or anterior surface* is convex in both directions and is transversely striated. In the median plane, it shows a vertical ***basilar sulcus*** which lodges the basilar artery.
2. Laterally, the surface is continuous with the middle cerebellar peduncle.
3. The ***trigeminal nerve*** is attached to this surface at the junction of the pons with the middle cerebellar peduncle. The nerve has two roots—a small motor root which lies medial to the much larger sensory root.
4. The attached abducent, facial and vestibulocochlear nerves are at the lower border of the ventral surface at the junction of pons and medulla oblongata.

Dorsal or Posterior Surface

The *dorsal or posterior surface* is hidden by the cerebellum, and forms the upper half of the floor of the fourth ventricle.

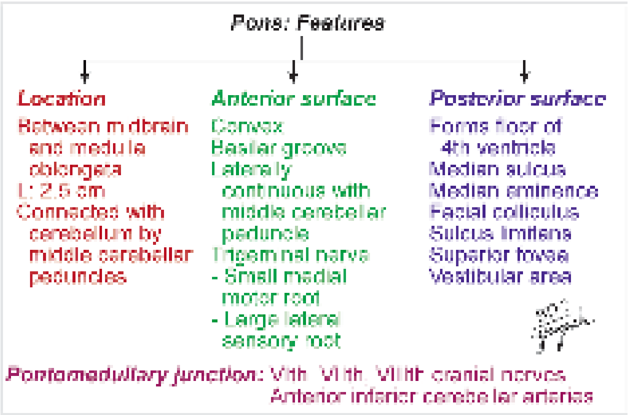
Borders

Pons has two borders—superior and inferior.

1. ***Superior border*:** Crus cerebri are attached here. III and IV nerves are also seen.
2. ***Inferior border*:** Lies at the junction of pons and medulla. VI, VII and VIII nerves lie at this border.

Note: Pontomedullary junction: It is represented by a shallow groove. The following cranial nerve emerges at the pontomedullary junction from medial to lateral: Abducent (VI), facial (VII) with nervus intermedius and vestibulocochlear nerves (VIII).

Flowchart 7.4: Pons: Features


Pons: Features
Location
Between midbrain and medulla oblongata
L: 2.5 cm
Connected with cerebellum by middle cerebellar peduncles
Anterior surface
Convex
Basilar groove
Laterally continuous with middle cerebellar peduncle
Trigeminal nerve
- Small medial motor root
- Large lateral sensory root
Posterior surface
Forms floor of 4th ventricle
Median sulcus
Median eminence
Facial colliculus
Sulcus limitans
Superior fovea
Vestibular area
Pontomedullary junction: VIth, VIIth, VIIIth cranial nerves
Anterior inferior cerebellar arteries

Competencies:
AN59.2 Draw and label transverse section of pons at the upper and lower level.
AN59.3 Enumerate cranial nerve nuclei in pons with their functional group.

INTERNAL STRUCTURE

In transverse sections, the pons is seen to be divisible into two parts (Fig. 7.8 and Flowchart 7.5):

1. Ventral or ***basilar part*** is continuous inferiorly with the pyramids of the medulla, and on each side with the cerebellum through the middle cerebellar peduncle.
2. Dorsal or ***tegmental part*** is a direct upward continuation of the medulla (excluding the pyramids).

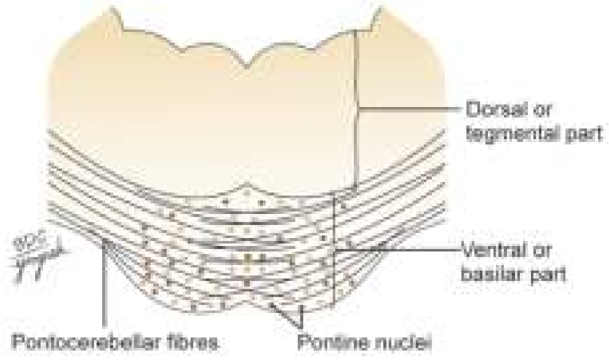
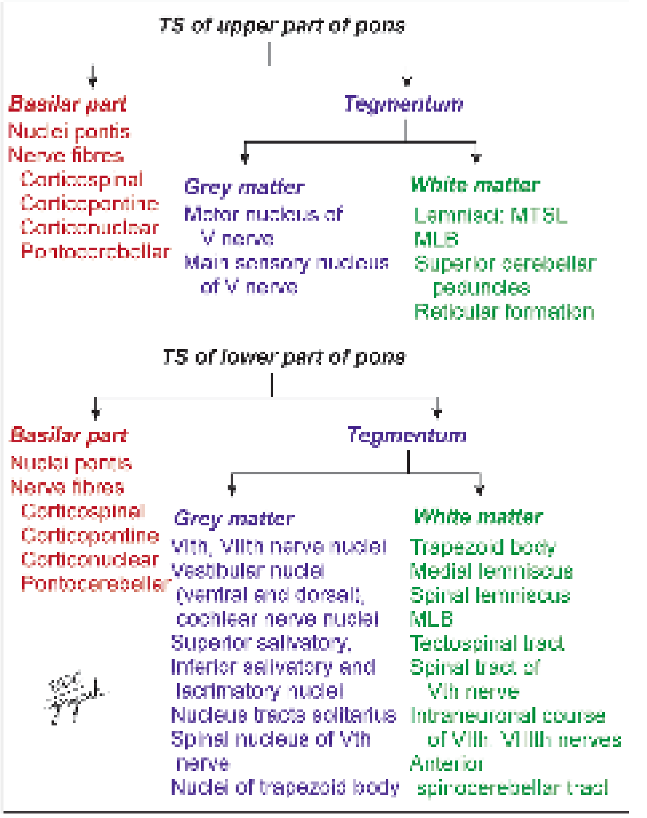

Dorsal or tegmental part
Ventral or basilar part
Pontocerebellar fibres
Pontine nuclei

Fig. 7.8: Parts of pons (TS of pons)

Flowchart 7.5: TS of pons


TS of upper part of pons
Basilar part
Nuclei pontis
Nerve fibres
Corticospinal
Corticopontine
Corticonuclear
Pontocerebellar
Tegmentum
Grey matter
Motor nucleus of V nerve
Main sensory nucleus of V nerve
White matter
Lemnisci: MTSL
MLB
Superior cerebellar peduncles
Reticular formation
TS of lower part of pons
Basilar part
Nuclei pontis
Nerve fibres
Corticospinal
Corticopontine
Corticonuclear
Pontocerebellar
Tegmentum
Grey matter
VIth, VIIth nerve nuclei
Vestibular nuclei (ventral and dorsal), cochlear nerve nuclei
Superior salivatory, Inferior salivatory and lacrimatory nuclei
Nucleus tractus solitarius
Spinal nucleus of Vth nerve
Nuclei of trapezoid body
White matter
Trapezoid body
Medial lemniscus
Spinal lemniscus
MLB
Tectospinal tract
Spinal tract of Vth nerve
Intraneuronal course of VIIth, VIIIth nerves
Anterior spinocerebellar tract

(MTSL: Medial, trigeminal, spinal, and lateral; MLB: Medial longitudinal bundle)

Basilar Part/Ventral Part

The basilar part of the pons has a uniform structure throughout its length.

Grey Matter

It is represented by the ***nuclei pontis*** which are scattered among longitudinal and transverse fibres. The pontine nuclei form an important part of the cortico-pontocerebellar pathway. Some of these nuclei get displaced during development, and form the arcuate nucleus (*see* medulla) and the pontobulbar body. Fibres from all these nuclei go to the opposite half of the cerebellum.

White Matter

It consists of longitudinal and transverse fibres.

1. The longitudinal fibres include:
   a. The *corticospinal* and *corticonuclear* (pyramidal) tracts.
   b. The *corticopontine* fibres ending in the pontine nuclei.
2. The transverse fibres are *pontocerebellar* fibres beginning from the pontine nuclei and going to the opposite half of the cerebellum, through the middle cerebellar peduncle.

Tegmental Part/Dorsal Part

However, the structure of the tegmental part differs in the upper and lower parts of the pons.

1. Tegmentum in the Lower Part of Pons

(Fig. 7.9, Flowchart 7.5)

Grey matter

1. The 6*th nerve nucleus* lies beneath the facial colliculus.
2. The 7*th nerve nucleus* lies in the reticular formation of the pons.
3. The vestibular and cochlear nuclei lie in relation to the inferior cerebellar peduncle. The *vestibular nuclei* lie deep to the vestibular area in the floor of the fourth ventricle, partly in the medulla and partly in the pons. They are divisible into four parts—superior, inferior, medial and lateral. They receive the fibres of the vestibular nerve, and give efferents to the cerebellum (vestibulocerebellar), the medial longitudinal bundle and the spinal cord (vestibulospinal tract arising in the lateral vestibular nucleus) and the lateral lemniscus.

   The dorsal and ventral *cochlear nuclei* are situated dorsal and ventral to the inferior cerebellar peduncle. They receive the fibres of the cochlear nerve, and give efferents mostly to the superior olivary nucleus and partly to nuclei of the corpus trapezoideum, and to nuclei of the lateral lemniscus. These fibres form the trapezoid body.
4. The spinal nucleus of the trigeminal nerve lies in the lateral part.
5. Other nuclei present include the superior salivatory and lacrimatory nuclei.
6. Reticular formation also present.

White matter

1. The *trapezoid body* or corpus trapezoideum is a transverse band of fibres lying just behind the ventral part of the pons. It consists of fibres that arise in the cochlear nuclei of both sides. It is a part of the auditory pathway.
2. The medial lemniscus forms a transverse band on either side of the midline, just behind the trapezoid body. It is joined by anterior spinothalamic tract.
3. The lateral spinothalamic tract (spinal lemniscus) lies lateral to the medial lemniscus.
4. The trigeminal lemniscus conveys fibres of second sensory neurons from the opposite spinal and sensory nuclei of trigeminal nerve.

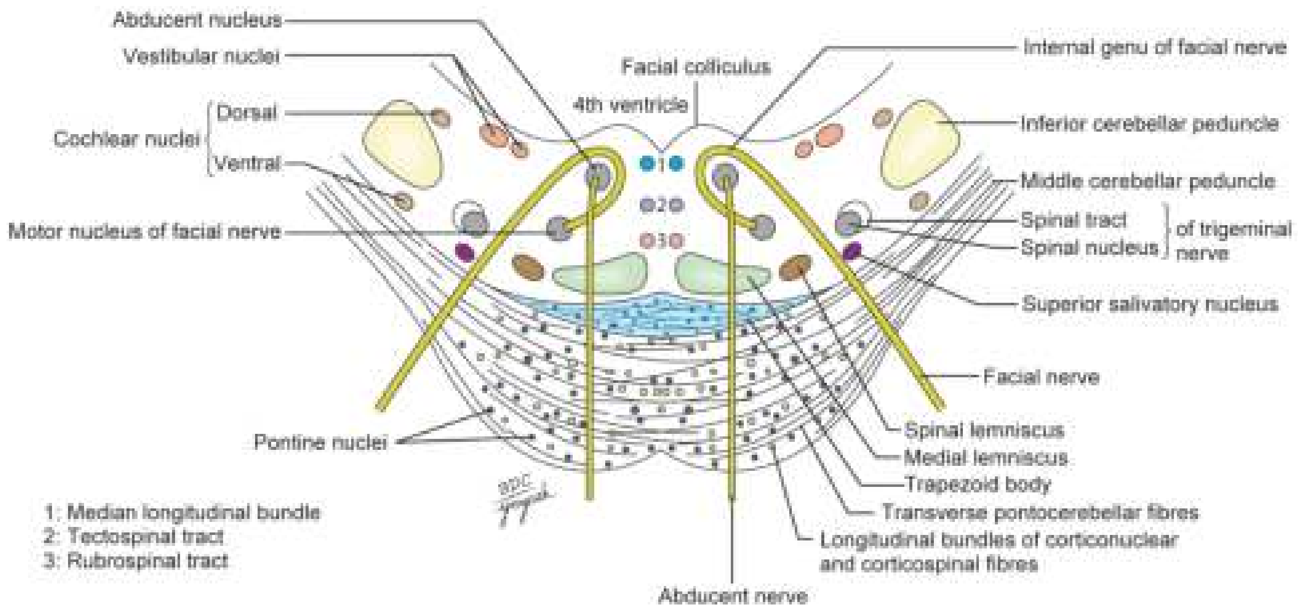

Abducent nucleus
Vestibular nuclei
Cochlear nuclei
Dorsal
Ventral
Motor nucleus of facial nerve
Facial colliculus
4th ventricle
1
2
3
Internal genu of facial nerve
Inferior cerebellar peduncle
Middle cerebellar peduncle
Spinal tract
Spinal nucleus
of trigeminal nerve
Superior salivatory nucleus
Facial nerve
Pontine nuclei
Spinal lemniscus
Medial lemniscus
Trapezoid body
Transverse pontocerebellar fibres
Longitudinal bundles of corticonuclear and corticospinal fibres
Abducent nerve
1: Median longitudinal bundle
2: Tectospinal tract
3: Rubrospinal tract

Fig. 7.9: TS of lower part of pons or TS at the level of facial colliculus

5. The inferior cerebellar peduncle lies lateral to the floor of the fourth ventricle.
6. The fibres of the facial nerve follow a peculiar course. They first pass backwards and medially to reach the medial side of the abducent nucleus. They then form a loop dorsal to the abducent nucleus. This loop is responsible for producing an elevation, the *facial colliculus*, in the floor of the fourth ventricle.

2. *Tegmentum in the Upper Part of Pons*

(Fig. 7.10, Flowchart 7.5)

Grey matter

1. The special features are the *motor, and superior sensory nuclei of the trigeminal nerve.* The motor nucleus is medial to the superior sensory nucleus.
2. Reticular formation contains pneumotaxic centre and apneustic centres in pons. These control respiration.

White matter

1. Immediately behind the ventral part of the pons, the bands of fibres made up (from medial to lateral side) of the medial lemniscus, the trigeminal lemniscus, the spinal lemniscus and the lateral lemniscus (MTSL) are present. The trigeminal lemniscus contains fibres arising in the spinal nucleus of the trigeminal nerve and travelling to the thalamus. The lateral lemniscus is a part of the auditory pathway. It is formed by fibres arising in nuclei lying in close relation to the trapezoid body (superior olivary nucleus and nucleus of trapezoid body).
2. The superior cerebellar peduncles lie dorsolateral to the fourth ventricle (replacing the inferior peduncle seen in the lower part of the pons).
3. The medial longitudinal bundle is made up of fibres that interconnect the nuclei of the cranial nerves III, IV, VI, VIII and the spinal root of the XI. It coordinates movements of the head and neck in response to stimulation of the cranial nerve VIII. However, the majority of fibres in the medial longitudinal bundle arise in the vestibular nuclei.

BLOOD SUPPLY

The pontine arteries are a number of small vessels which come off at right angles from either side of the basilar artery and supply the pons and adjacent parts of the brain.

Competency:

AN59.4 Describe the anatomical basis of clinical conditions affecting the pons (Locked-in syndrome, pontine haemorrhage, Foville syndrome, Raymond syndrome, Millard-Gubler syndrome).

CLINICAL NEUROANATOMY

Pontine haemorrhage: Occurs due to rupture of pontine branches of basilar artery. This entity has following features:

a. Bilateral paralysis of face and limbs due to involvement of VII nerve nucleus and all corticospinal fibres.
b. Deep coma due to damage to the reticular formation.
c. Hyperpyrexia due to cutting off of the temperature regulating fibres from the hypothalamus.
d. Pinpoint pupil due to damage to sympathetic ocular fibres and unopposed action of sphincter pupillae muscle which is innervated by parasympathetic fibres.

Pontine haemorrhage is usually fatal.

Cerebellopontine angle (Fig. 7.11)**:** The anatomical structures located in the cerebellopontine angle include choroid plexuses of IV ventricle, flocculus, VII and VIII cranial nerves. A tumour, acoustic neuroma, in this angle arises usually in relation to VIII nerve. Features are:

a. Ipsilateral facial paralysis and loss of taste in anterior two-thirds of tongue and hyperacusis due to damage to fibres of facial nerve.
b. Deafness and vertigo due to damage to both the parts of VIII nerve.

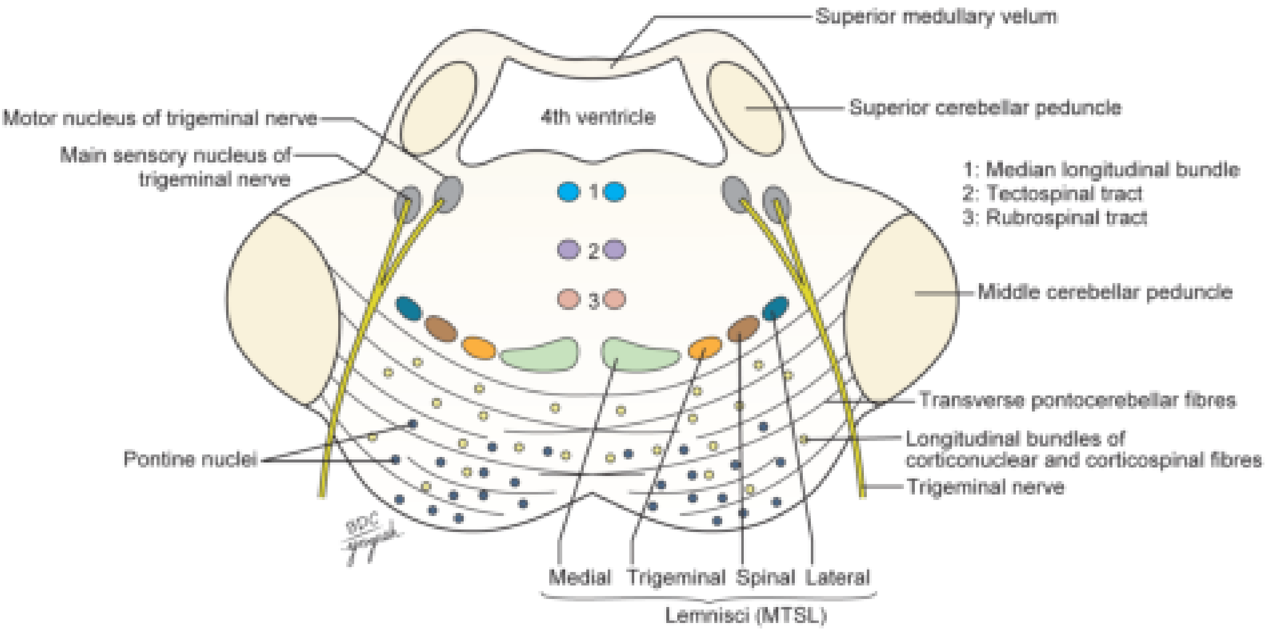

Superior medullary velum
Motor nucleus of trigeminal nerve
4th ventricle
Superior cerebellar peduncle
Main sensory nucleus of trigeminal nerve
1: Median longitudinal bundle
2: Tectospinal tract
3: Rubrospinal tract
1
2
3
Middle cerebellar peduncle
Transverse pontocerebellar fibres
Longitudinal bundles of corticonuclear and corticospinal fibres
Pontine nuclei
Trigeminal nerve
Medial
Trigeminal
Spinal
Lateral
Lemnisci (MTSL)

Fig. 7.10: TS of upper pons

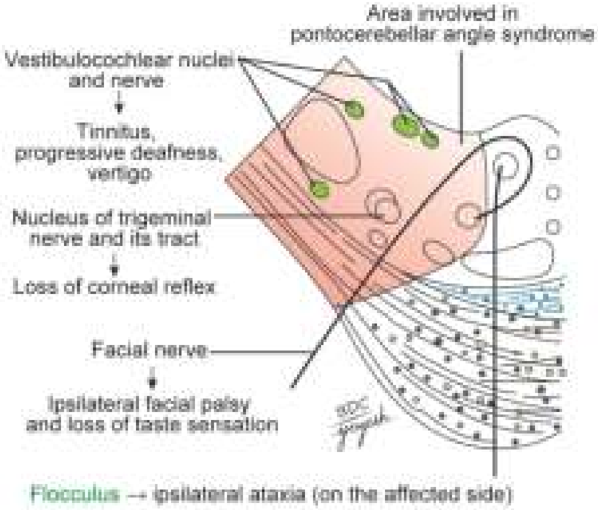

Area involved in pontocerebellar angle syndrome
Vestibulocochlear nuclei and nerve
Tinnitus, progressive deafness, vertigo
Nucleus of trigeminal nerve and its tract
Loss of corneal reflex
Facial nerve
Ipsilateral facial palsy and loss of taste sensation
Flocculus → ipsilateral ataxia (on the affected side)

Fig. 7.11: Cerebellopontine angle tumour

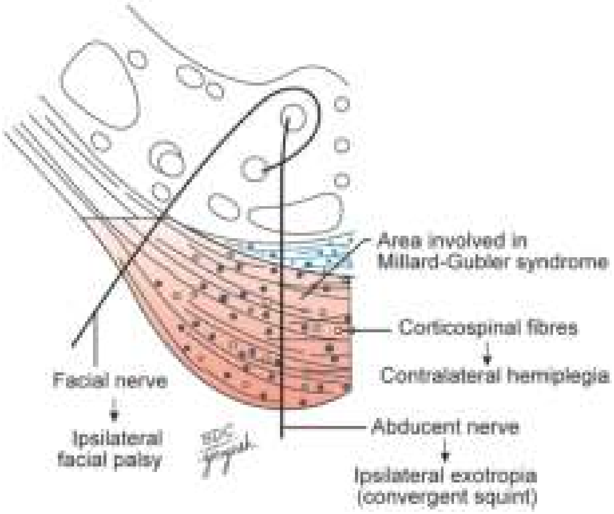

Area involved in Millard-Gubler syndrome
Corticospinal fibres
Contralateral hemiplegia
Facial nerve
Ipsilateral facial palsy
Abducent nerve
Ipsilateral exotropia (convergent squint)

Fig. 7.12: Millard-Gubler syndrome

c. Ataxia on the affected side due to involvement of the flocculus.

d. Absence of corneal reflex on the side of lesion due to damage to nucleus of V nerve including its spinal tract.

Millard-Gubler syndrome (Fig. 7.12)**:** In this condition, there is damage to fibres of VI and VII nerves along with pyramidal fibres. Features are:

a. Ipsilateral facial paralysis due to damage to VII nerve; there is paralysis of facial muscles on the same side.

b. Ipsilateral loss of abduction of the eye due to damage to VI nerve. Due to unopposed action of adductors of eye, there is ipsilateral medial squint and diplopia on looking towards paralysed side.

c. Contralateral hemiplegia due to lesion of the pyramidal fibres.

Tumours of pons: Astrocytoma is the most common tumour of brainstem, usually in childhood. Signs and symptoms vary according to area of origin of tumour.

Foville's syndrome: It occurs due to blockage of perforating branch of a basilar artery supplying the dorsal part of pons. In this syndrome, damage to abducent nerve nucleus produces ipsilateral exotropia, and damage to facial nerve nucleus produces ipsilateral facial paralysis.

Note: ***Lemnisci:***

1. *Medial lemniscus* (*Reil's band*): It has second order neurons of tract of Goll and Burdach. It carries conscious proprioception, discriminative touch sensation and vibration sensation.
2. *Trigeminal lemniscus*: It conveys pain and temperature sensations from face. Its fibres are derived from the spinal nucleus of trigeminal nerve.
3. *Spinal lemniscus*: It consists of 2nd order neurons of lateral spinothalamic tract (carries pain and temperature sensations from opposite half of body) and ventral spinothalamic tract (carries crude touch and crude pressure sensations from opposite half of body).
4. *Lateral lemniscus*: It consists of third order neurons of auditory pathway. They are derived from superior olivary nucleus (cochlear nuclei → superior olivary nucleus → trapezoid body and its nuclei → lateral lemniscus).

[*Mnemonics:* ***Mahanagar Telephone Sitam (Nigam) Limited (MTSL)*** (from medial to lateral): **M** – Medial lemniscus; **T** – Trigeminal lemniscus; **S** – Spinal lemniscus; **L** – Lateral lemniscus]

MIDBRAIN

The midbrain is also called the *mesencephalon.* It is 2 cm long and connects the hindbrain with the forebrain. Its cavity is known as the cerebral aqueduct of Sylvius (French anatomist 1478–1555). It connects the third ventricle with the fourth ventricle (Fig. 7.13).

Location: The midbrain passes through the tentorial notch, and is related on each side to the parahippocampal gyri, the optic tracts, the posterior cerebral artery, the basal vein, the trochlear nerve, and the geniculate bodies (Flowchart 7.6). Anteriorly, it is related to the

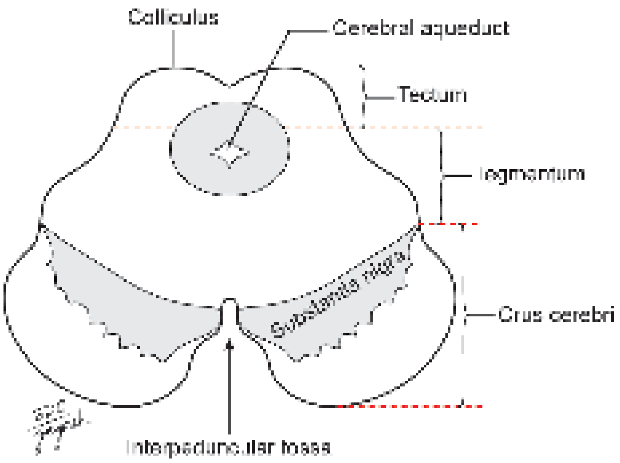
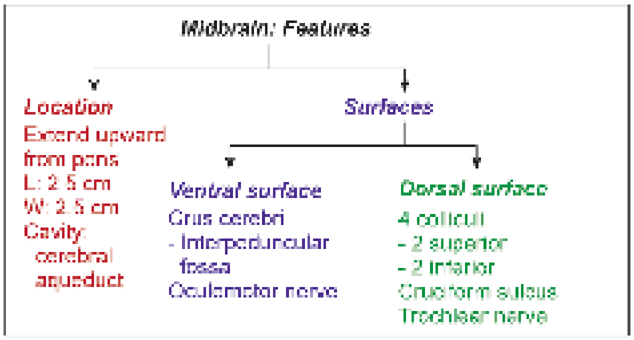

Colliculus
Cerebral aqueduct
Tectum
Tegmentum
Substantia nigra
Crus cerebri
Interpeduncular fossa

Fig. 7.13: Parts of midbrain

Flowchart 7.6: Midbrain: Features


Midbrain: Features
Location
Extend upward from pons
L: 2.5 cm
W: 2.5 cm
Cavity: cerebral aqueduct
Surfaces
Ventral surface
Crus cerebri
- Interpeduncular fossa
Oculomotor nerve
Dorsal surface
4 colliculi
- 2 superior
- 2 inferior
Cruciform sulcus
Trochlear nerve

interpeduncular structures, and posteriorly to the splenium of the corpus callosum, the great cerebral vein, the pineal body, and the posterior ends of the right and left thalami.

Dimensions

- *Length*: 2.5 cm
- *Width:* 2.5 cm.

Competency:
AN61.1 Identify external and internal features of midbrain.

EXTERNAL FEATURES

Ventral Surface

Ventral surface presents ***crus cerebri***. It is crossed by optic tract, basal vein, posterior cerebral and superior cerebellar arteries. From the medial side, of crus cerebri ***oculomotor nerve*** emerges (Figs 7.1 and 7.2).

Dorsal Surface

On the dorsal aspects, ***superior and inferior colliculi*** are present. They are called together as corpora quadrigemina (quadruplet bodies). The superior colliculus is connected to the lateral geniculate body by the *superior brachium*.

Likewise, the inferior colliculus is connected to the medial geniculate body by the *inferior brachium*.

Cruciform sulcus separates the four colliculi from each other.

The ***trochlear nerve*** emerges one on each side of frenulum veli. These nerves decussate in each superior medullary velum. Further, it curls around the lateral aspect of cerebral peduncles and runs forwards.

Competency:
AN61.2 Describe internal features of midbrain at the level of superior and inferior colliculus.

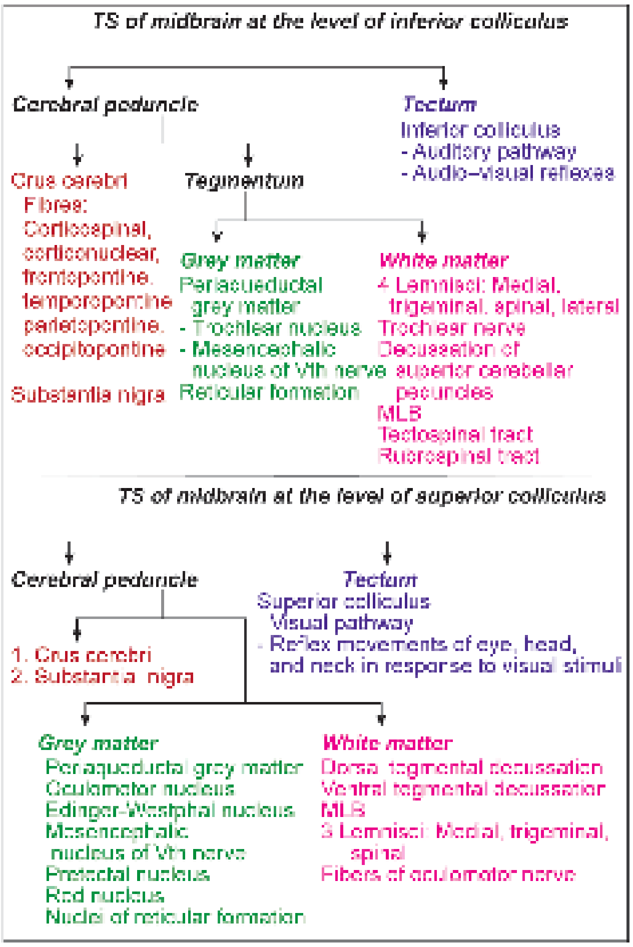
INTERNAL STRUCTURE

In the transverse section, the midbrain shows the following parts:

1. The ***tectum*** is the part posterior to aqueduct. It is made up of the right and left superior and inferior colliculi (Flowchart 7.7).
2. Each half of the midbrain anterior to the aqueduct is called the ***cerebral peduncle***. Each cerebral peduncle is subdivided into:
    a. Crus cerebri, anteriorly
    b. Substantia nigra, in the middle
    c. Tegmentum, posteriorly (Flowchart 7.7).
3. The *periaqueductal grey matter*.

It is studied conveniently by examining sections, at the level of the inferior colliculi and at the level of the superior colliculi.

Flowchart 7.7: TS of midbrain


TS of midbrain at the level of inferior colliculus
Cerebral peduncle
Tectum
Inferior colliculus
- Auditory pathway
- Audio–visual reflexes
Crus cerebri
Fibres:
Corticospinal,
corticonuclear,
frontopontine,
temporopontine
parietopontine,
occipitopontine
Substantia nigra
Tegmentum
Grey matter
Periaqueductal grey matter
- Trochlear nucleus
- Mesencephalic nucleus of Vth nerve
Reticular formation
White matter
4 Lemnisci: Medial, trigeminal, spinal, lateral
Trochlear nerve
Decussation of superior cerebellar peduncles
MLB
Tectospinal tract
Rubrospinal tract
TS of midbrain at the level of superior colliculus
Cerebral peduncle
Tectum
Superior colliculus
Visual pathway
- Reflex movements of eye, head, and neck in response to visual stimuli
1. Crus cerebri
2. Substantia nigra
Grey matter
Periaqueductal grey matter
Oculomotor nucleus
Edinger-Westphal nucleus
Mesencephalic nucleus of Vth nerve
Pretectal nucleus
Red nucleus
Nuclei of reticular formation
White matter
Dorsal tegmental decussation
Ventral tegmental decussation
MLB
3 Lemnisci: Medial, trigeminal, spinal
Fibers of oculomotor nerve

Transverse Section of Midbrain at the Level of Inferior Colliculi

Grey Matter

1. The ***central (periaqueductal) grey matter*** contains:
    a. The ***nucleus of the trochlear nerve*** in the ventromedial part.
    b. The ***mesencephalic nucleus*** of the trigeminal nerve in the lateral part. The mesencephalic nucleus is made up of unipolar cells (first neuron) and receives proprioceptive impulses from the muscles of mastication, the facial and ocular muscles, the teeth (Fig. 7.14) and temporomandibular joint.
2. The ***inferior colliculus*** receives afferents from the lateral lemniscus, and gives efferents to the medial geniculate body. In the past, it has been considered as the centre for auditory reflexes, but the available evidence indicates that it helps in localizing the source of sounds.
3. The ***substantia nigra*** is a lamina of grey matter made up of deeply pigmented nerve cells. It is concerned with muscle tone (Fig. 7.14).
4. Reticular formation also present.

White Matter

1. The ***crus cerebri*** contains:
    a. The corticospinal tract in the middle.
    b. Frontopontine fibres in the medial one-sixth.

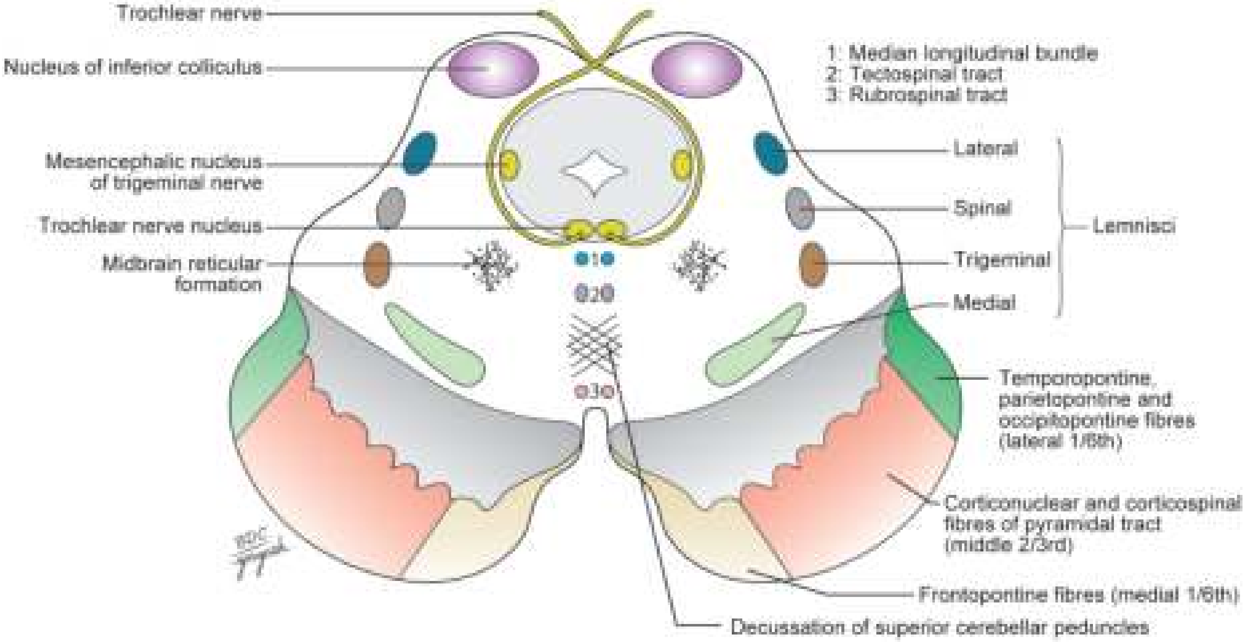

Trochlear nerve
Nucleus of inferior colliculus
Mesencephalic nucleus of trigeminal nerve
Trochlear nerve nucleus
Midbrain reticular formation
1: Median longitudinal bundle
2: Tectospinal tract
3: Rubrospinal tract
1
2
3
Lateral
Spinal
Trigeminal
Medial
Lemnisci
Temporopontine, parietopontine and occipitopontine fibres (lateral 1/6th)
Corticonuclear and corticospinal fibres of pyramidal tract (middle 2/3rd)
Frontopontine fibres (medial 1/6th)
Decussation of superior cerebellar peduncles

Fig. 7.14: TS of midbrain at the level of inferior colliculus

   c. Temporopontine, parietopontine and occipitopontine fibres in the lateral one-sixth.
2. The ***tegmentum*** contains ascending tracts as follows:
   a. The ***lemnisci*** (medial, trigeminal, spinal and lateral) are arranged in the form of a band in which they lie in the order mentioned (from medial to lateral side) like a necklace.
   b. The *decussation of the superior cerebellar peduncles* is seen in the median plane.
   c. The *medial longitudinal bundle* lies in close relation to the trochlear nucleus (somatic efferent column).
   d. The tectospinal tract and the rubrospinal tract are present.
3. The trochlear nerve passes laterally and dorsally round the central grey matter. It decussates in the superior medullary velum, and emerges lateral to the frenulum veli.

Transverse Section of Midbrain at the Level of Superior Colliculi

Grey Matter

1. The ***central grey matter*** contains:
   a. Nucleus of ***oculomotor nerve*** with Edinger-Westphal nucleus in the ventromedial part.
   b. ***Mesencephalic nucleus*** of the trigeminal nerve in the lateral part. The oculomotor nuclei of the two sides are very close to each other (Fig. 7.15).
2. ***Superior colliculus*** receives afferents from the retina (visual), and various other centres. It gives efferents to the spinal cord (tectospinal tract). It controls reflex movements of the eyes, and of the head and neck in response to visual stimuli (Fig. 7.15).
3. ***Pretectal nucleus*** lies deep to the superolateral part of the superior colliculus. It receives afferents from the lateral roots of the optic tract. It gives efferents to the Edinger-Westphal nuclei of both sides. The pretectal nucleus is an important part of the pathway for light reflex and the consensual reflex. Its lesion causes Argyll Robertson pupil in which the light reflex is lost but accommodation reflex remains intact.
4. ***Red nucleus*** is about 0.5 cm in diameter. It receives afferents from the superior cerebellar peduncle, globus pallidus, subthalamic nucleus and cerebral cortex. It gives efferents to the spinal cord (*rubrospinal tract*), reticular formation, thalamus, olivary nucleus, subthalamic nucleus, etc. It has an inhibitory influence on muscle tone (Fig. 7.16).
5. ***Substantia nigra*** is concerned with muscle tone. Reticular formation also present.

White Matter

1. The ***crus cerebri*** has the same tracts as described above.
2. The ***tegmentum*** contains the following:
   a. The same lemnisci as seen in the lower part except for the lateral lemniscus which has terminated in the inferior colliculus.
   b. The decussation of the tectospinal and tectobulbar tracts forms the *dorsal tegmental decussation*.
   c. The decussation of the rubrospinal tracts forms the *ventral tegmental decussation*.
   d. Medial longitudinal bundle.
   e. Emerging fibres of oculomotor nerve.
3. The ***tectum*** shows the posterior commissure connecting the two superior colliculi.

BLOOD SUPPLY

Most of the blood supply is derived from branches of the basilar artery. Besides this, it also receives from following arteries.

1. Posterior cerebral
2. Superior cerebellar
3. Posterior communicating
4. Anterior choroidal

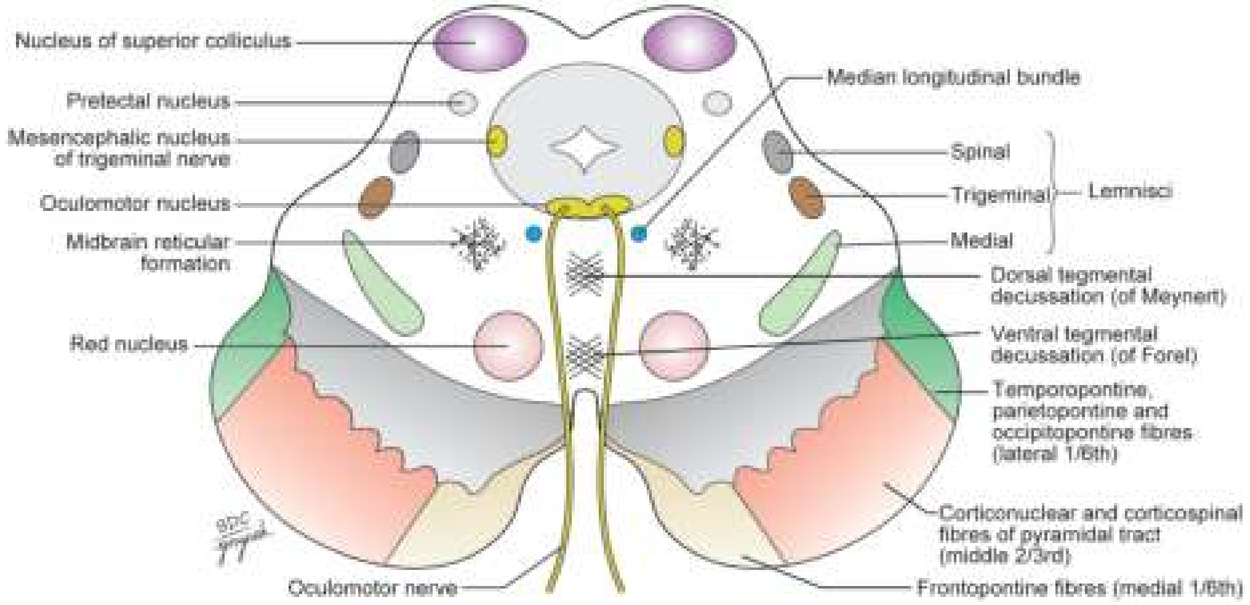

Nucleus of superior colliculus
Pretectal nucleus
Mesencephalic nucleus of trigeminal nerve
Oculomotor nucleus
Midbrain reticular formation
Red nucleus
Oculomotor nerve
Median longitudinal bundle
Spinal
Trigeminal
Medial
Lemnisci
Dorsal tegmental decussation (of Meynert)
Ventral tegmental decussation (of Forel)
Temporopontine, parietopontine and occipitopontine fibres (lateral 1/6th)
Corticonuclear and corticospinal fibres of pyramidal tract (middle 2/3rd)
Frontopontine fibres (medial 1/6th)
BDC

Fig. 7.15: TS of midbrain at the level of superior colliculus

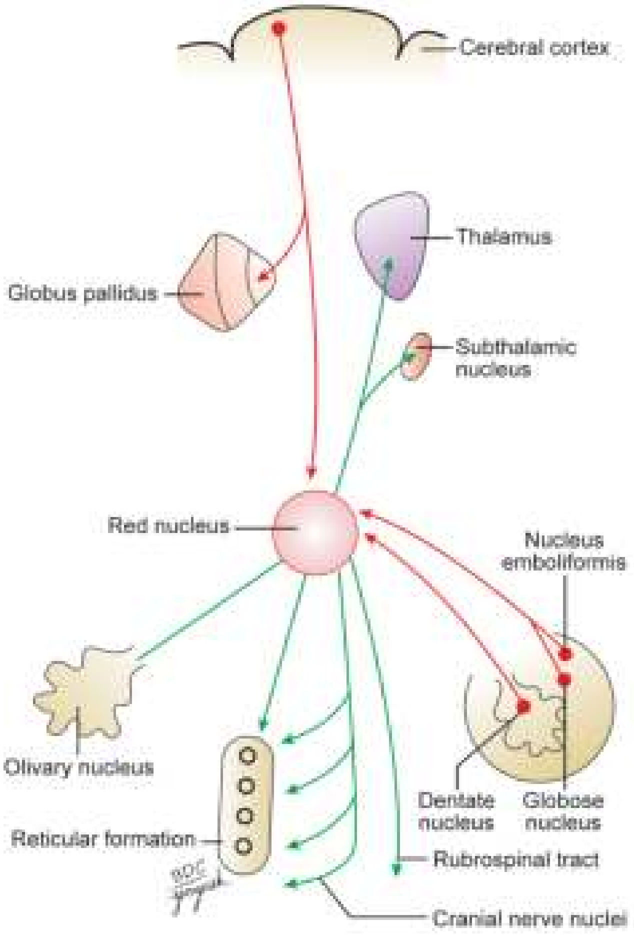

Cerebral cortex
Thalamus
Globus pallidus
Subthalamic nucleus
Red nucleus
Nucleus emboliformis
Olivary nucleus
Reticular formation
Dentate nucleus
Globose nucleus
Rubrospinal tract
Cranial nerve nuclei
BDC

Fig. 7.16: Connections of red nucleus

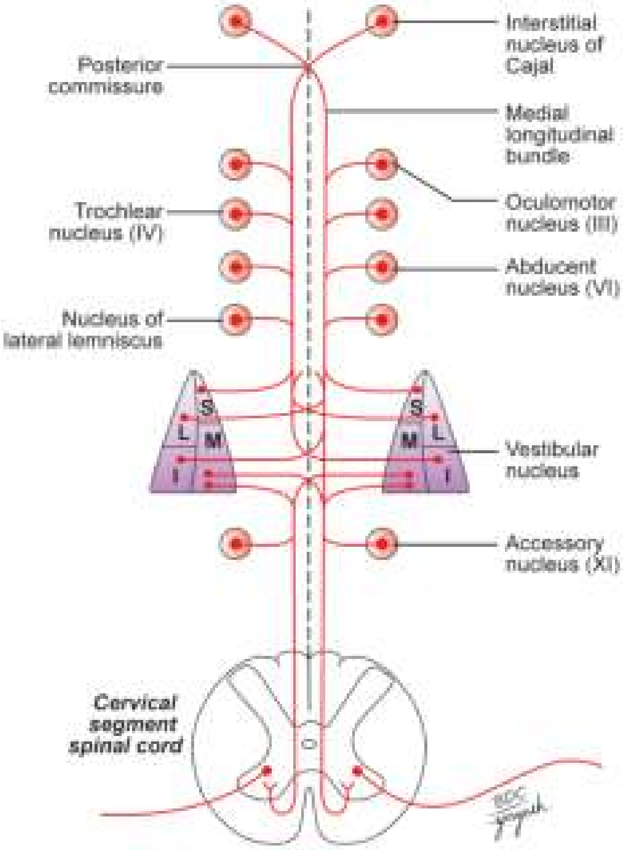

Interstitial nucleus of Cajal
Posterior commissure
Medial longitudinal bundle
Oculomotor nucleus (III)
Trochlear nucleus (IV)
Abducent nucleus (VI)
Nucleus of lateral lemniscus
S
L
M
I
Vestibular nucleus
Accessory nucleus (XI)
Cervical segment spinal cord
BDC

Fig. 7.17: Connections of medial longitudinal bundle

MEDIAL LONGITUDINAL BUNDLE

Main constituent fibres of medial longitudinal bundle (Fig. 7.17) are the fibres from left and right medial vestibular nuclei. These fibres reach up to interstitial nucleus of Cajal at the upper end of aqueduct. The lower end of the fibres reach up to cervical segments of spinal cord.

The bundle connects the cranial nerve nuclei of III, IV, VI, VIII and spinal root of XI nerves. It is also connected to the anterior horn cells which supply muscles of the neck.

This bundle integrates movements of eyes, and neck. It also maintains equilibrium.

***Competency*:**
AN61.3 Describe the anatomical basis of clinical conditions affecting the midbrain (Weber's syndrome, Benedikt's syndrome, Parinaud's syndrome).

CLINICAL NEUROANATOMY

Weber's syndrome (Fig. 7.18): This syndrome involves III nerve nucleus and corticospinal fibres occur due to blockage or rupture of branch of posterior cerebral artery supplying the midbrain. Features are:

a. Hemiplegia on the opposite side due to involvement of corticospinal fibres.
b. Pupil points downwards and laterally due to paralysis of III nerve. There is lateral squint on ipsilateral side due to unopposed action of lateral rectus muscle. There is also contralateral paralysis of lower quarter of face (supranuclear facial palsy).

Benedikt's syndrome (Fig. 7.19): In this condition, most of the tegmentum of midbrain is damaged. Lesion includes loss of medial lemniscus, red nucleus, superior cerebellar peduncle and fibres of III nerve. Features are:

a. Loss of proprioception due to lesion of medial lemniscus.
b. Pupil points downwards and laterally due to injury to III nerve.
c. Tremors and twitching of opposite side due to damage to red nucleus and superior cerebellar peduncle.

Parinaud's syndrome: Lesion of superior colliculi leads to this syndrome. Features include weakness of upward gaze and vertical nystagmus due to lesion of superior colliculus.

Argyll Robertson pupil: In this condition, light reflex is lost but accommodation reflex is retained due to lesion in the vicinity of pretectal nucleus.

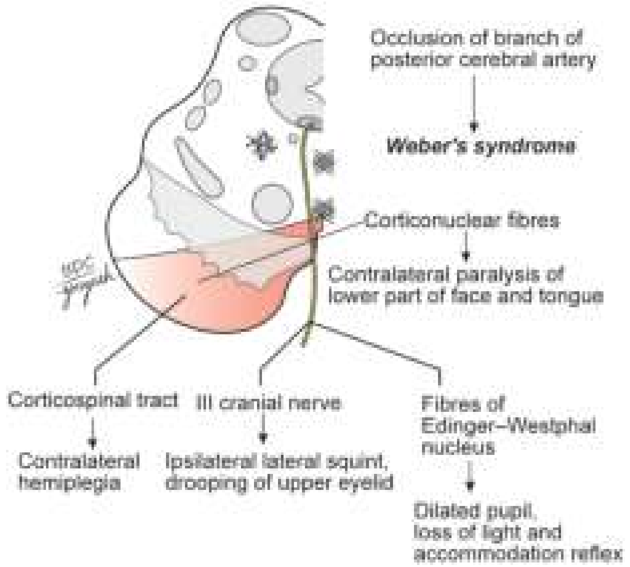

Occlusion of branch of posterior cerebral artery
Weber's syndrome
Corticonuclear fibres
Contralateral paralysis of lower part of face and tongue
Corticospinal tract
Contralateral hemiplegia
III cranial nerve
Ipsilateral lateral squint, drooping of upper eyelid
Fibres of Edinger–Westphal nucleus
Dilated pupil, loss of light and accommodation reflex
BDC gargesh

Fig. 7.18: Weber syndrome (Transverse section through the upper part of the midbrain, affected zone is shown by light red colour)

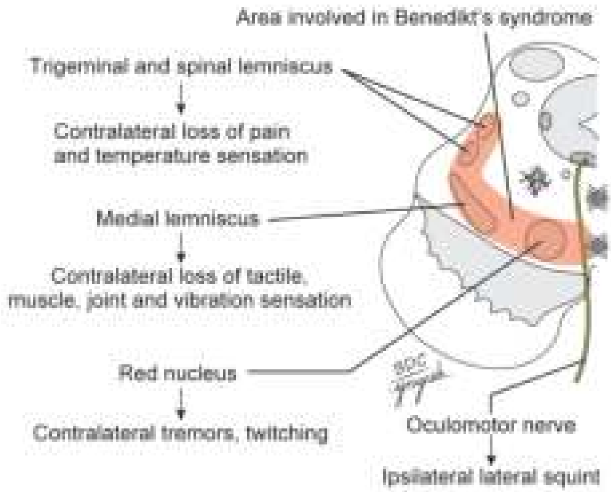

Area involved in Benedikt's syndrome
Trigeminal and spinal lemniscus
Contralateral loss of pain and temperature sensation
Medial lemniscus
Contralateral loss of tactile, muscle, joint and vibration sensation
Red nucleus
Contralateral tremors, twitching
Oculomotor nerve
Ipsilateral lateral squint
BDC gargesh

Fig. 7.19: Benedikt's syndrome (Transverse section through the upper part of the midbrain, affected zone is shown by light red colour)

Note: Locked-in syndrome is a rare disorder that shows all voluntary muscles paralysis except for the extraocular muscles. It usually results from brainstem damage, such as a stroke. Patients cannot speak or move but can communicate through eye movements.

VIDEO

Video 4.5 Brainstem

Facts to Remember

- Pyramidal decussation cuts off the anterior horn which forms nucleus of 1st cervical nerve and nucleus of spinal accessory nerve.
- Nucleus gracilis and nucleus cuneatus are equivalent of the nuclei in the posterior horn of spinal cord.
- At the lower section of pons, fibres of cochlear nuclei form trapezoid body which forms lateral lemniscus. Nuclei of VI, VII and VIII cranial nerves are present here.
- At the upper section of pons, some of the nuclei forming trigeminal nerve are situated. The nerve lies at the junction of pons with the middle cerebellar peduncle.
- Section at the level of inferior colliculus shows 4 lemnisci: Medial, trigeminal, spinal and lateral (MTSL) from medial to lateral side. It also shows nucleus of IV nerve, the delicate cranial nerve.
- Section at the level of superior colliculus shows prominent red nucleus. It also shows III nerve nucleus with Edinger-Westphal nucleus.

BDC's Anatomy *e*-book

1. Development of medulla oblongata
2. Development of pons
3. Development of midbrain
4. Further reading
5. Viva voce questions

Chapter 8

Cerebellum

Cerebellum (Latin *small brain*), though small in size (weighs about 150 g), subserves important functions for maintaining tone, posture, and equilibrium of the body. It is the largest part of the hindbrain and second largest part of the brain (Plate 8.1 and Figs 8.1a and b).

The grey matter is highly folded to accommodate millions of neurons in a small area and the arrangement is called ***'arbor vitae'*** (tree of life). The structure of cerebellum is uniform throughout, i.e. homotypical.

Note:

1. Cerebellum controls the same side of the body directly or indirectly.
2. The cerebellum does not initiate movement, but it contributes to coordination, precision and accurate timing.

Location

The cerebellum is situated in the posterior cranial fossa behind the pons and medulla. The 4th ventricle separates the cerebellum from pons and upper part of medulla oblongata. It is separated from the cerebrum by tentorium cerebelli (Flowchart 8.1).

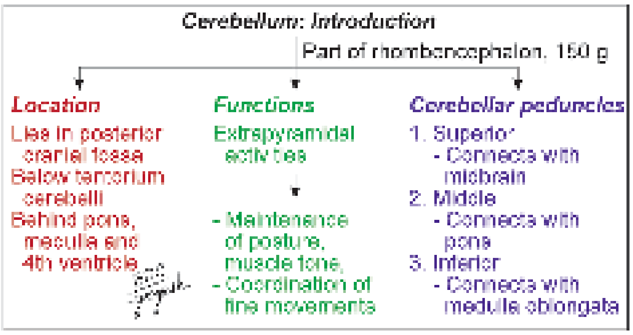
Relations

Anteriorly: Fourth ventricle, pons and medulla.
Posteroinferiorly: Squamous occipital bone.
Superiorly: Tentorium cerebelli.

Cavity

The 4th ventricle separates the cerebellum from the pons and the upper part of medulla oblongata.

Flowchart 8.1: Cerebellum: Introduction


Cerebellum: Introduction
Part of rhombencephalon, 150 g
Location
Lies in posterior cranial fossa
Below tentorium cerebelli
Behind pons, medulla and 4th ventricle
Functions
Extrapyramidal activities
- Maintenance of posture, muscle tone,
- Coordination of fine movements
Cerebellar peduncles
1. Superior
- Connects with midbrain
2. Middle
- Connects with pons
3. Inferior
- Connects with medulla oblongata

Cerebellar Peduncles

The cerebellum is connected with the brainstem by three pairs of large white fibres called cerebellar peduncles. They are as follows:

1. Superior cerebellar peduncle connects with midbrain.
2. Middle cerebellar peduncle connects with pons.
3. Inferior cerebellar peduncle connects with medulla oblongata.

Competency:
AN60.1 Describe and demonstrate external and internal features of cerebellum.

EXTERNAL FEATURES

The cerebellum is oval and flattened from above downward. Its transverse diameter is larger than the anteroposterior diameter (Flowchart 8.2). The surface of cerebellum shows numerous fissures. The cerebellum has (Fig. 8.2):

1. *Three parts*: Two cerebellar hemispheres, one vermis
2. *Two surfaces*: Superior and inferior
3. *Two notches*: Anterior and posterior
4. *Three prominent fissures*: Horizontal, posterolateral, fissura prima.

Parts of Cerebellum

It consists of:

1. Two *cerebellar hemispheres* – two lateral portions
2. *Vermis* – narrow median portion that connects two cerebellar hemispheres.

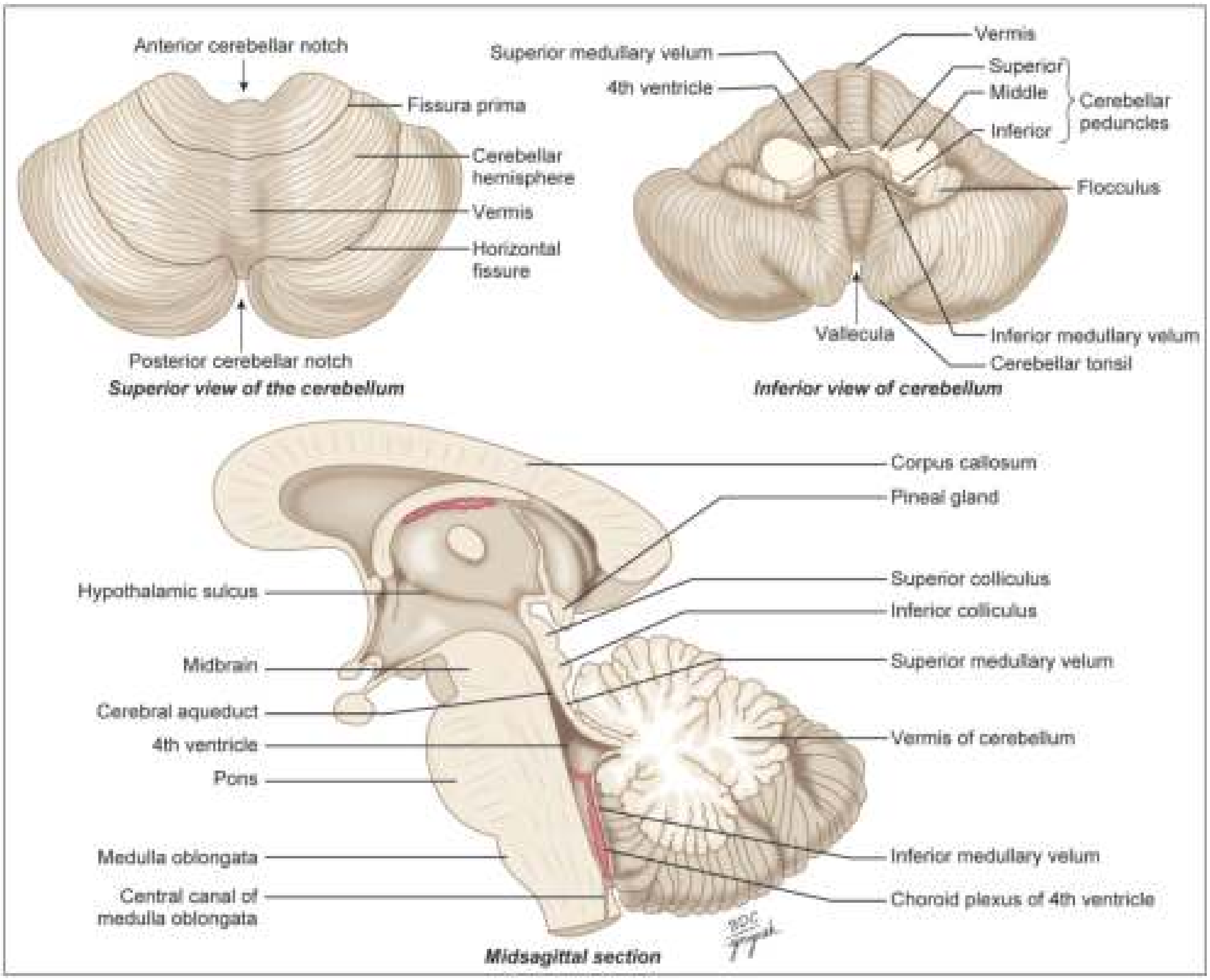
Surfaces

Superior surface: It is convex. *Superior vermis* (superior part of vermis) is continuous with superior surface of cerebellar hemispheres (Fig. 8.2).

Inferior surface: It has deep groove or notch in the median plane which is called *vallecula* (Fig. 8.2).

Vallecula (*vallecula cerebelli*) (= groove, in Latin) is a deep notch on the inferior surface of that separates cerebellar hemispheres.

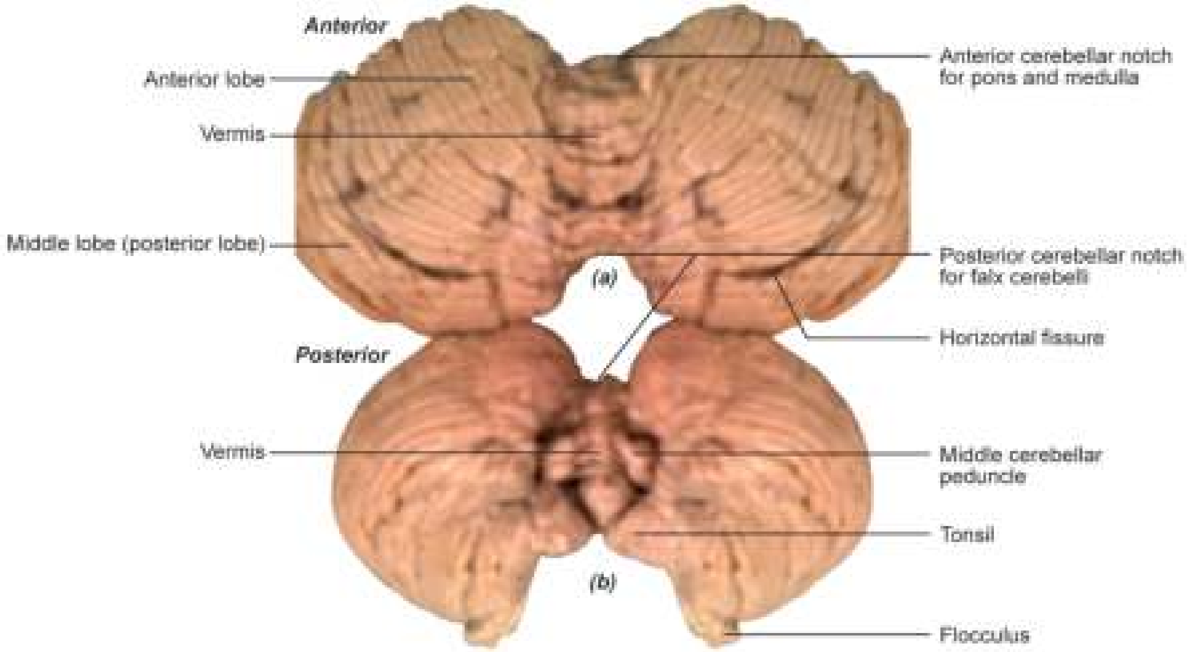
Plate 8.1: Cerebellum


Anterior cerebellar notch
Fissura prima
Cerebellar hemisphere
Vermis
Horizontal fissure
Posterior cerebellar notch
Superior medullary velum
4th ventricle
Vermis
Superior
Middle
Inferior
Cerebellar peduncles
Flocculus
Vallecula
Inferior medullary velum
Cerebellar tonsil
Corpus callosum
Pineal gland
Hypothalamic sulcus
Superior colliculus
Inferior colliculus
Midbrain
Superior medullary velum
Cerebral aqueduct
4th ventricle
Vermis of cerebellum
Pons
Medulla oblongata
Inferior medullary velum
Central canal of medulla oblongata
Choroid plexus of 4th ventricle

Superior view of the cerebellum

Inferior view of cerebellum

Midsagittal section


Anterior
Anterior lobe
Vermis
Middle lobe (posterior lobe)
Anterior cerebellar notch for pons and medulla
Posterior cerebellar notch for falx cerebelli
Horizontal fissure
(a)
Posterior
Vermis
Middle cerebellar peduncle
Tonsil
(b)
Flocculus

Figs 8.1a and b: (a) Superior and (b) inferior surface of cerebellum (gross specimen)

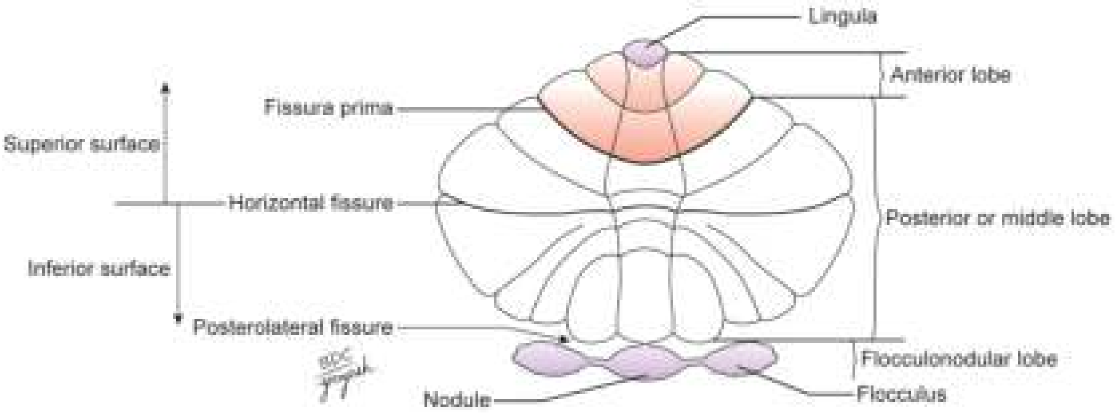
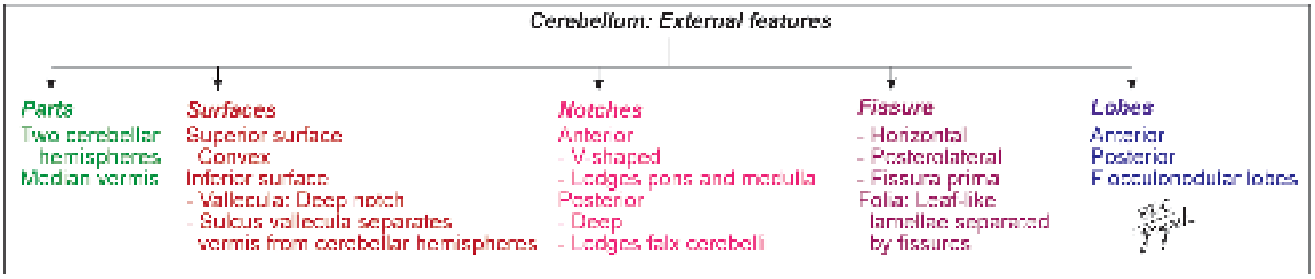

Lingula
Anterior lobe
Fissura prima
Superior surface
Horizontal fissure
Posterior or middle lobe
Inferior surface
Posterolateral fissure
Flocculonodular lobe
Nodule
Flocculus

Fig. 8.2: Lobes, main fissures and surfaces of cerebellum (schematic representation)

Flowchart 8.2: Cerebellum: External features


Cerebellum: External features
Parts
Two cerebellar hemispheres
Median vermis
Surfaces
Superior surface
Convex
Inferior surface
- Vallecula: Deep notch
- Sulcus vallecula separates vermis from cerebellar hemispheres
Notches
Anterior
- V-shaped
- Lodges pons and medulla
Posterior
- Deep
- Lodges falx cerebelli
Fissure
- Horizontal
- Posterolateral
- Fissura prima
Folia: Leaf-like lamellae separated by fissures
Lobes
Anterior
Posterior
Flocculonodular lobes

Sulcus vallecula: It is a sulcus that separates inferior vermis from inferior surface of cerebellar hemispheres. It is the lateral limit of vallecula.

Notches

Anterior cerebellar notch is wide, shallow, V-shaped notch on the anterior part of cerebellum. It lodges the pons and medulla.

Posterior cerebellar notch is deep and narrow. It lodges falx cerebelli (fold of dura mater).

Fissures

There are numerous transversely running furrows of varying depth on the cerebellar surface.

Folia: These are narrow leaf-like lamellae separated by fissures. Each folium consists of core of white matter covered by grey matter.

Three fissures are prominent and consistent, and they are as follows:

1. ***Horizontal fissure*****:** It separates superior and inferior surface of cerebellum.
2. ***Posterolateral fissure*****:** It lies on the inferior surface of cerebellum and separates the flocculonodular lobe from the rest of the cerebellum (corpus cerebelli).
3. ***Primary fissure*** (*fissura prima*): It is V-shaped fissure on the superior surface with its apex directed posterior.

The cerebellum is divided into two parts by posterolateral fissure:

1. Flocculonodular lobe
2. Corpus cerebelli.

Corpus cerebelli is divided into anterior and posterior lobes by fissura prima.

Tonsil is a part of cerebellum on its inferior surface. In raised intracranial pressure, tonsils may protrude into the foramen magnum.

PARTS AND LOBES OF CEREBELLUM

The cerebellum is subdivided into numerous small parts by fissures. Each fissure cuts the vermis and both hemispheres. Table 8.1 shows part of vermis with its respective part of cerebellar hemisphere. The *horizontal fissure* separates the superior surface from the inferior surface (Fig. 8.3).

The *primary fissure (fissura prima)* separates the anterior lobe from the middle lobe on the superior surface of the

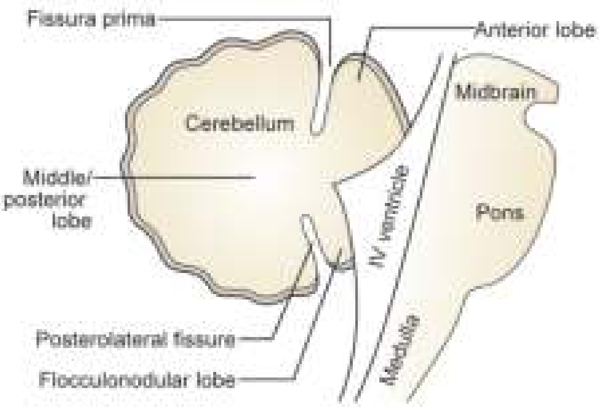

Fissura prima
Anterior lobe
Midbrain
Cerebellum
Middle/ posterior lobe
IV ventricle
Pons
Medulla
Posterolateral fissure
Flocculonodular lobe

Fig. 8.3: Anatomical lobes of the cerebellum

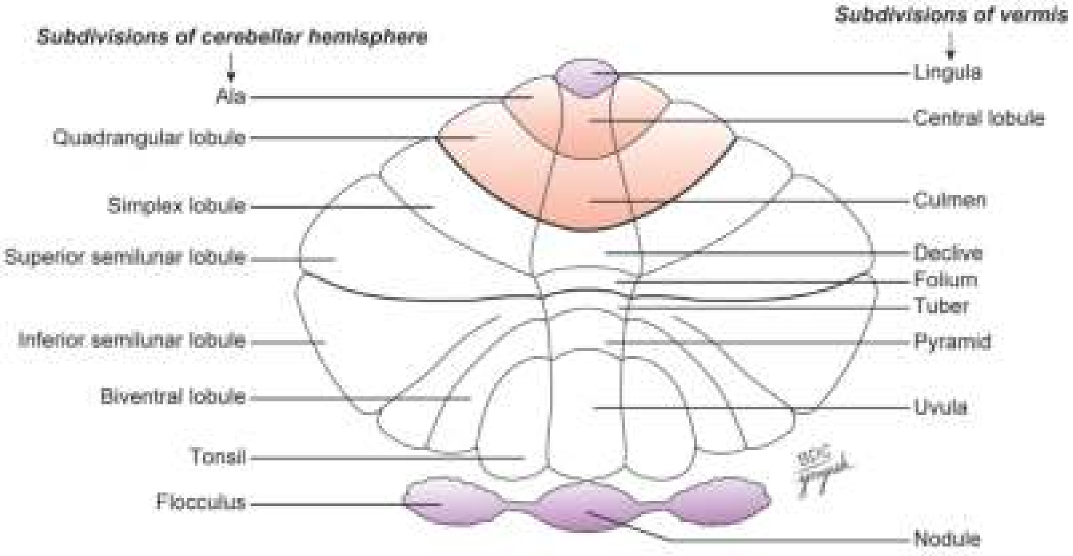

Subdivisions of cerebellar hemisphere
Ala
Quadrangular lobule
Simplex lobule
Superior semilunar lobule
Inferior semilunar lobule
Biventral lobule
Tonsil
Flocculus
Subdivisions of vermis
Lingula
Central lobule
Culmen
Declive
Folium
Tuber
Pyramid
Uvula
Nodule

Fig. 8.4: Subdivisions of cerebellar hemispheres and vermis (schematic representation)

TABLE 8.1: Subdivisions or lobules of cerebellum

Lobes	*Subdivisions of vermis*	*Subdivisions of each cerebellar hemisphere*
Anterior lobe	Lingula	—
	Central lobule	Ala
	Culmen	Quadrangular lobule
Posterior lobe	Declive	Simplex lobule
	Folium	Superior semilunar lobule
	Tuber	Inferior semilunar lobule
	Pyramid	Biventral lobule
	Uvula	Tonsil
Flocculonodular lobe	Nodule	Flocculus

[*Mnemonics* for subdivisions of cerebellar vermis: **L**azy **C**at **D**ie **F**or **T**aka **P**izza **U**n**N**ecessarily]

cerebellum. The *posterolateral fissure* separates the middle lobe from the flocculonodular lobe on the inferior surface.

The various parts of cerebellum are shown in Fig. 8.4. Where both the superior and inferior surfaces of the cerebellum are drawn in one plane. The upper part of the diagram, above the horizontal fissure, represents the superior surface; and the lower part, below the horizontal fissure represents the inferior surface. However, the *lingula* does not have any lateral extension.

The subdivisions or lobules of cerebellum are given in Table 8.1.

MORPHOLOGICAL DIVISIONS OF CEREBELLUM

Based on function and phylogenetic (evolutionary) aspect, the cerebellum is divided into three parts:

1. ***Archicerebellum:*** The archicerebellum phylogenetically is the oldest part of the cerebellum to appear in evolution in aquatic vertebrates. It includes the flocculonodular lobe and the lingula. It is chiefly vestibular in its connections. It controls the axial musculature and the bilateral movements used for locomotion and maintenance of equilibrium (Fig. 8.5).

2. ***Paleocerebellum:*** The paleocerebellum is the next part of the cerebellum to appear in terrestrial vertebrates with the appearance of limbs. It is made up of the anterior lobe (except lingula), and the pyramid and uvula of the

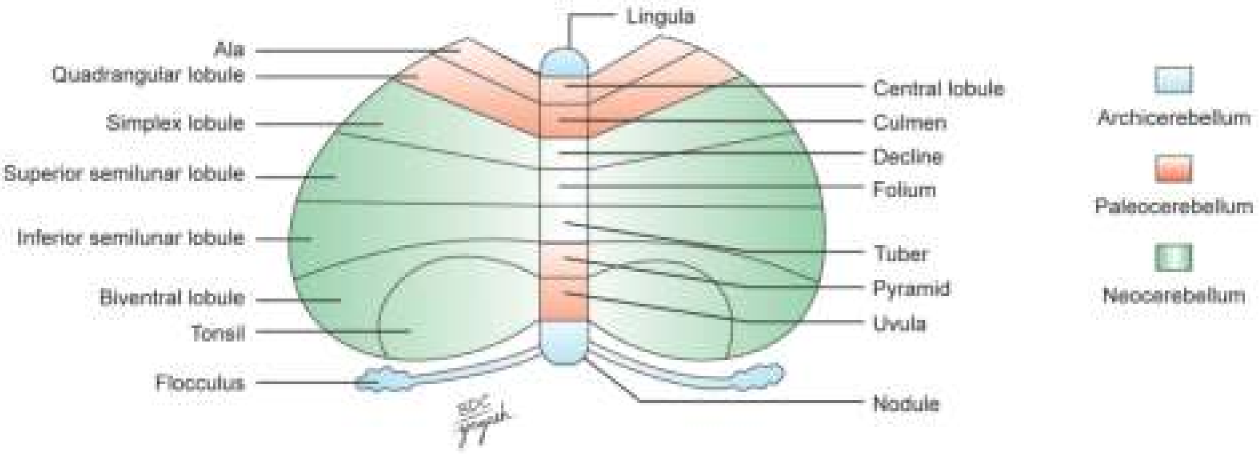

Lingula
Ala
Quadrangular lobule
Simplex lobule
Superior semilunar lobule
Inferior semilunar lobule
Biventral lobule
Tonsil
Flocculus
Central lobule
Culmen
Decline
Folium
Tuber
Pyramid
Uvula
Nodule
Archicerebellum
Paleocerebellum
Neocerebellum

Fig. 8.5: Functional subdivisions of cerebellum

inferior vermis. Its connections are chiefly spinocerebellar. It controls tone, posture and crude movements of the limbs.

3. *Neocerebellum:* The neocerebellum is the newest part of the cerebellum to develop. It is made up of the posterior/middle lobe (the largest part of the cerebellum) except the pyramid and uvula of the inferior vermis. It is primarily concerned with the regulation of fine movements of the body. Table 8.1 depicts the morphological and functional divisions of cerebellum.

Competencies:

AN60.2 Describe connections of cerebellar cortex and intra-cerebellar nuclei.

AN64.1 Describe and identify the microanatomical features of spinal cord, cerebellum and cerebrum.

INTERNAL FEATURES AND HISTOLOGY OF CEREBELLUM

The cerebellum is highly folded to accommodate millions of neurons in a small area. These foldings are called *arbor vitae*. The cerebellum has:

1. Outer grey matter – cerebellar cortex
2. Inner white matter – cerebellar medulla
3. Cerebellar nuclei – grey matter embedded deep in the medulla.

The cerebellar cortex is uniform throughout (***homotypical***). Cerebellar cortex shows three layers: Outer molecular layer, middle Purkinje cell layer, and inner granular layer (Plate 8.2 and Fig. 8.6).

1. ***Molecular layer*:** It lies just deep to the pia mater. It consists of few cells and more fibres. It has stellate cells in superficial part and few basket cells in deeper part. The molecular layer shows numerous branching processes of Purkinje cells, axons of granule cells, and climbing fibres.
2. ***Purkinje cell layer*:** This layer consists of a single row of Purkinje cell bodies that are arranged between molecular and granular layer. The Purkinje cells are large, flask-shaped neurons. Dendrites of Purkinje cells arise from apex of flask and enter into the molecular layer. A single axon arises from their base that passes through the granular layer and white matter to the cerebellar nuclei.
3. ***Granular layer:*** It lies between Purkinje cell layer and white matter. It stains dark with haematoxylin because of closely packed, numerous, small granule cells. The granular layer has granule cells and Golgi cells. Granule cells are small neurons with round nucleus. Golgi cell are large, stellate cells.

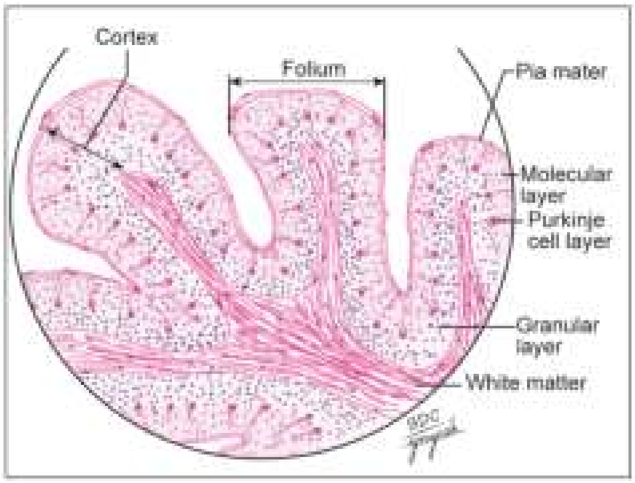
The granule cells has mossy fibres that bring information from pons to granule cells (pontocerebellar fibres). Climbing fibres and axons of Purkinje cells pass through the granular layer.

Table 8.2 shows the neurons of cerebellum.

The white matter is composed of fibres and neuroglial cells.

Note: ***Cerebellar glomeruli*:** Mossy fibres end as dilated terminals. This dilated terminal is surrounded by dendrites of granule cells and axons of Golgi cells. Mossy fibre terminal with surrounding dendrites and axons form light-stained areas in granular layer. These areas are called *glomeruli of cerebellum*.

Plate 8.2: Histology of cerebellum



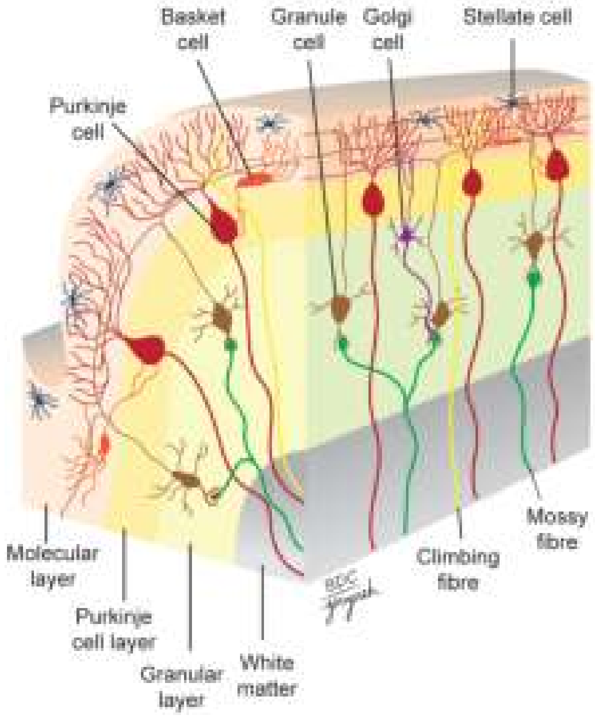


Fig. 8.6: Cerebellar neurons and layers

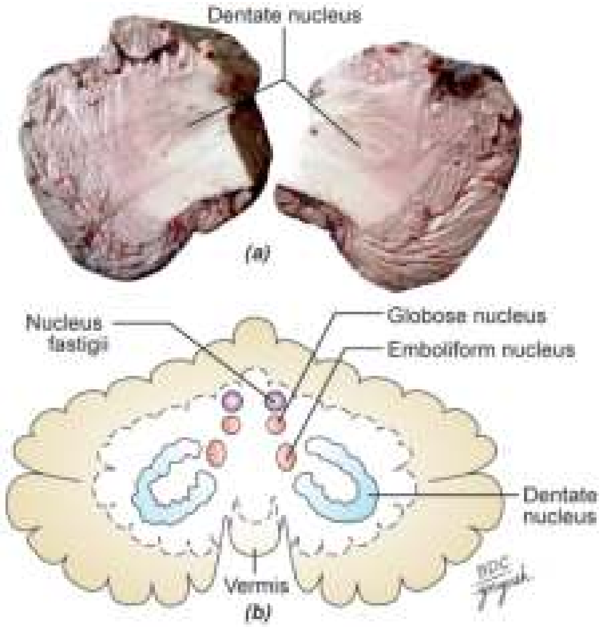
CEREBELLAR NUCLEI

There are four cerebellar nuclei on each side (Figs 8.7a and b). These are masses of grey matter embedded deeply in the substance of white matter of cerebellum.

1. *Dentate nucleus:* It is the largest cerebellar nucleus. It has a shape like a crumpled purse. Its hilus faces medially. It is the nucleus of neocerebellum and highly evolved in human.
2. *Emboliform nucleus:* It is oval. It lies lateral to globose nucleus and medial to dentate nucleus.
3. *Globose nucleus:* It is round. It lies between emboliform and fastigial nuclei. The emboliform and globose nuclei are the part of paleocerebellum. They are collectively called nucleus interpositus.

TABLE 8.2: Neurons of cerebellum

Neurons	*Location*	*Features*	*Dendrites*	*Axon*
Stellate cells	Just beneath the surface of cerebellum in molecular layer	Star-shaped (stellate) dendritic trees	Confined to molecular layer Synapse with parallel fibre of granule cells	Confined to molecular layer Synapse with dendrites of Purkinje cells
Basket cells	Deeper part of molecular layer	Form basket-like structure	Few dendrites Synapse with parallel fibres bodies of granule cells, Purkinje cells, climbing and mossy fibres	Synapse with Purkinje cell
Purkinje cells	Purkinje cell layer	Large flask-shaped cells	Arborize in molecular layer	Single axon to deep cerebellar nuclei
Granule cells	Granular layer	Small, spherical neurons	Dendrites form glomeruli with mossy fibres	Axon runs parallel to each other and enters into molecular layer
Golgi neurons	Superficial part of granular layer	Large stellate cells GABAergic inhibitory neurons	Dendrites enter molecular synapse with parallel fibres	Axon ends in glomeruli



Figs 8.7a and b: Positions of intracerebellar nuclei

4. *Nucleus fastigii*: It lies close to midline in the vermis just dorsal to the 4th ventricle. It is spherical. It is the nucleus of archicerebellum.

WHITE MATTER OF CEREBELLUM

The white matter of cerebellum forms the medulla of cerebellum. It has typical tree-like branching appearance called *arbor vitae cerebelli*. The white matter consists of intrinsic, afferent and efferent fibres.

1. *Intrinsic fibres*: They do not leave the cerebellum and remain confined to cerebellum. They connect the different regions of cerebellum.
2. *Projection fibres*: They are afferent and efferent fibres. They connect the cerebellum with the other parts of brain. They are arranged into three large bundles on each side as superior, middle, and inferior cerebellar peduncles.

Sensory Fibres of Cerebellum

Cerebellum receives input from mossy fibres and climbing fibres.

1. *Climbing fibres:* These are olivocerebellar fibres (axons) arising from inferior olivary nucleus. They synapse in molecular layer with Purkinje cells (one fibre for one cell).
2. *Mossy fibres:* These are other than olivocerebellar fibres. These include vestibulocerebellar, pontocerebellar, and spinocerebellar fibres. Mossy fibres have dilated terminals in granular layer. They synapse with dendrites of granule cells and axons of Golgi cells. This synapse forms light staining cerebellar glomeruli (Fig. 8.8).

CONNECTIONS OF CEREBELLUM

The fibres entering or leaving the cerebellum are grouped to form three peduncles (Latin *small foot*) which connect the cerebellum to the midbrain, the pons and the medulla (Figs 8.9 and 8.10 and Flowchart 8.3).

Inferior cerebellar peduncle: It connects the cerebellum with medulla oblongata. It is also called *restiform body*. It consists of mainly afferent fibres that carry sensory information.

Afferent fibres

1. *Posterior spinocerebellar fibres* from ipsilateral thoracic nuclei (Clarke's column) of spinal cord.

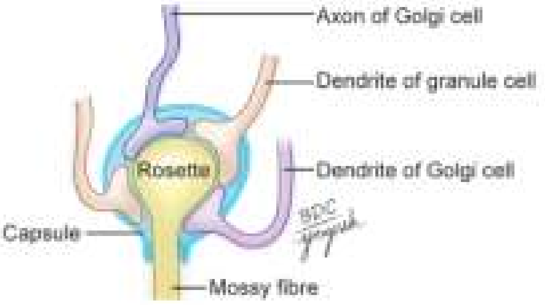
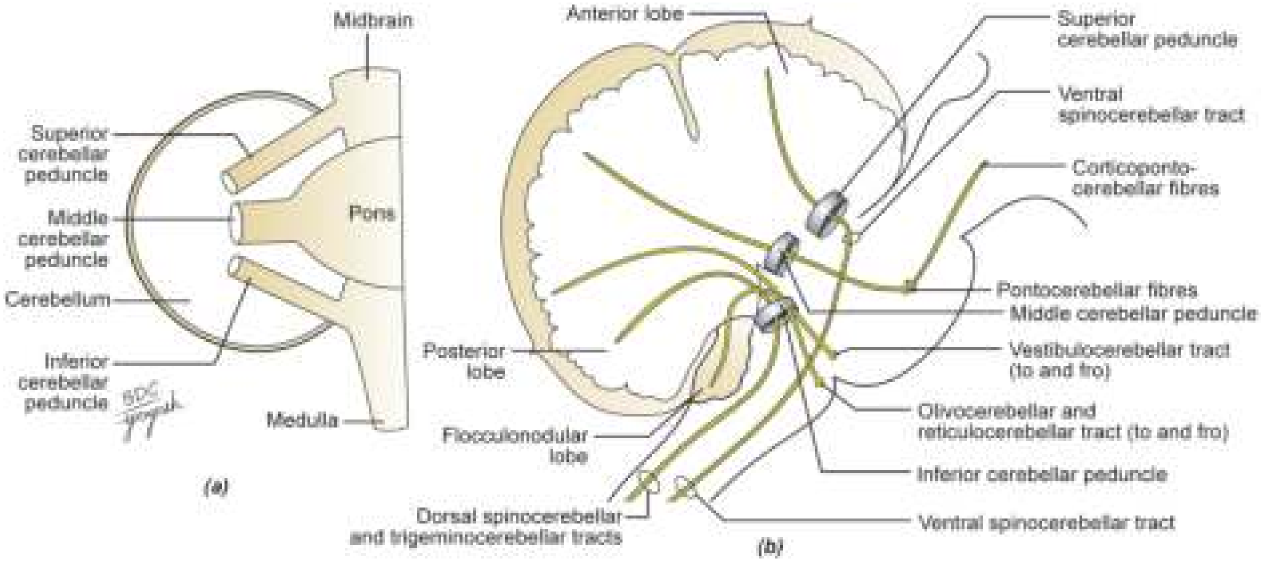


Fig. 8.8: Structure of cerebellar glomerulus


Midbrain
Superior cerebellar peduncle
Middle cerebellar peduncle
Pons
Cerebellum
Inferior cerebellar peduncle
Medulla
(a)
Anterior lobe
Superior cerebellar peduncle
Ventral spinocerebellar tract
Corticoponto-cerebellar fibres
Pontocerebellar fibres
Middle cerebellar peduncle
Posterior lobe
Vestibulocerebellar tract (to and fro)
Olivocerebellar and reticulocerebellar tract (to and fro)
Flocculonodular lobe
Inferior cerebellar peduncle
Dorsal spinocerebellar and trigeminocerebellar tracts
Ventral spinocerebellar tract
(b)

Figs 8.9a and b: (a) The three cerebellar peduncles and (b) main connections of cerebellum

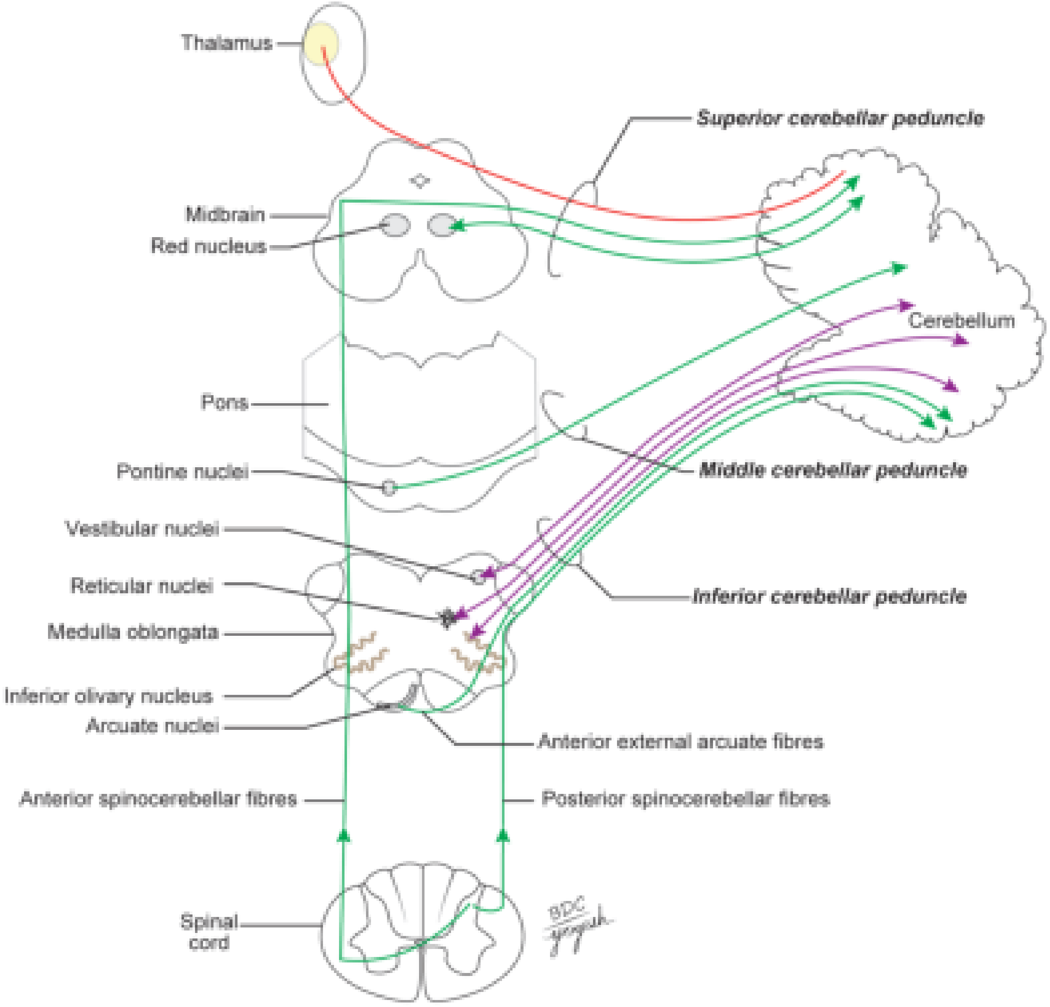
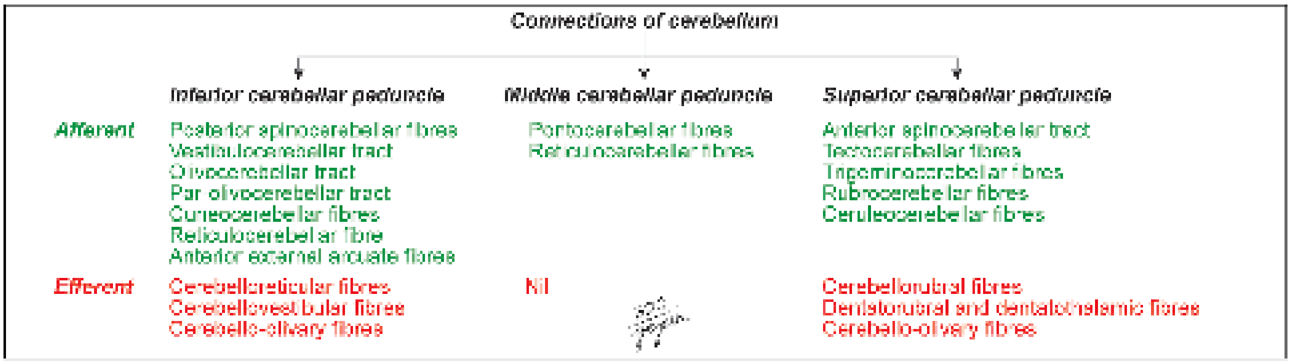

Thalamus
Superior cerebellar peduncle
Midbrain
Red nucleus
Cerebellum
Pons
Pontine nuclei
Middle cerebellar peduncle
Vestibular nuclei
Reticular nuclei
Inferior cerebellar peduncle
Medulla oblongata
Inferior olivary nucleus
Arcuate nuclei
Anterior external arcuate fibres
Anterior spinocerebellar fibres
Posterior spinocerebellar fibres
Spinal cord

Fig. 8.10: Major connections of cerebellum

2. *Vestibulocerebellar tract* from vestibular nerve and vestibular nuclei.
3. *Olivocerebellar tract* from opposite inferior olivary nucleus (they form climbing fibres).
4. *Par-olivocerebellar tract* from opposite medial olivary nuclei.
5. *Cuneocerebellar* or *posterior external arcuate fibres* from ipsilateral accessory cuneate nuclei.
6. *Reticulocerebellar fibre* from reticular nuclei of medulla oblongata.
7. *Anterior external arcuate fibres* from both arcuate nuclei.

Flowchart 8.3: Connections of cerebellum



Connections of cerebellum

	Inferior cerebellar peduncle	Middle cerebellar peduncle	Superior cerebellar peduncle
Afferent	Posterior spinocerebellar fibres Vestibulocerebellar tract Olivocerebellar tract Par olivocerebellar tract Cuneocerebellar fibres Reticulocerebellar fibre Anterior external arcuate fibres	Pontocerebellar fibres Reticulocerebellar fibres	Anterior spinocerebellar tract Tectocerebellar fibres Trigeminocerebellar fibres Rubrocerebellar fibres Ceruleocerebellar fibres
Efferent	Cerebelloreticular fibres Cerebellovestibular fibres Cerebello-olivary fibres	Nil	Cerebellorubral fibres Dentatorubral and dentatothalamic fibres Cerebello-olivary fibres

Efferent fibres:

1. *Cerebelloreticular fibres* from both fastigial nuclei to reticular formation.
2. *Cerebellovestibular fibres* from ipsilateral flocculonodular lobe and fastigial nuclei of both sides to vestibular nuclei.
3. *Cerebello-olivary fibres.*

Middle cerebellar peduncle

Afferent fibres:

1. *Pontocerebellar fibres* from opposite pontine nuclei
2. *Reticulocerebellar fibres* from pontine reticular nuclei.

Efferent fibres: Nil.

Superior cerebellar peduncle

Afferent fibres:

1. *Anterior spinocerebellar tract* from spinal cord.
2. *Tectocerebellar fibres* from tectum (superior and inferior colliculi) of midbrain.
3. *Trigeminocerebellar fibres* from superior sensory nucleus of V nerve.
4. *Rubrocerebellar fibres* from red nucleus.
5. *Ceruleocerebellar fibres* from locus coeruleus (located in the pons).

Efferent fibres:

1. *Cerebellorubral fibres* from globose and emboliform nucleus to contralateral red nucleus.
2. *Dentatorubral* and *dentatothalamic fibres* from dentate nucleus to opposite red nucleus and thalamus, respectively.
3. *Cerebello-olivary fibres* from dentate nucleus to contralateral olivary nucleus.

BLOOD SUPPLY

Arterial Supply

The cerebellum is supplied by three pairs of cerebellar arteries:

1. Superior cerebellar artery – branch of basilar artery.
2. Anterior inferior cerebellar artery – branch of basilar artery.
3. Posterior inferior cerebellar artery – branch of vertebral artery.

Venous Drainage

1. Superior cerebellar veins drain into straight, transverse, and superior petrosal sinuses.
2. Inferior cerebellar veins drain into the transverse and inferior petrosal sinuses.

FUNCTIONS OF CEREBELLUM

1. Cerebellum controls the same side of the body. Its influence is ipsilateral.
2. The *neocerebellum* coordinates voluntary movements so that they are smooth, balanced and accurate. Neocerebellum is responsible for fine tuning of motor performance for precise movements. It helps in planning and production of skilled movements along with cerebrum.
3. Cerebellum controls tone, posture and equilibrium. This is chiefly done by the archicerebellum and paleocerebellum.
4. Cerebellum controls movements of eyeballs. It controls and coordinates these by affecting agonists, antagonists and synergists. It also helps in learning of special motor skills. It plays a role in cognition.
5. Flocculonodular lobe is connected to vestibular nuclei. It is involved in maintenance of muscle tone and posture. Spinocerebellum, vermis and intermediate regions receive afferents from motor cortex via corticopontocerebellar fibres.
6. All sensory information from muscles, joints, cutaneous, auditory and visual parts are relayed here. Spinocerebellar tracts carry information from the same side.
7. Vermis controls axial muscles, and thus maintains posture. Paramedian areas are involved in control of distal group of muscles to bring smooth coordinated activity.
8. Cerebellum functions as '***comparator***'. It receives information from cerebrum and spinal cord. It corrects and modifies ongoing movements through thalamocortical projections, reticulospinal and rubrospinal tracts.

Note: It has been seen by functional magnetic resonance imaging (fMRI) that if fingers of right hand are moved repetitively, the activity is seen in precentral gyrus of left cerebral cortex and in anterior quadrangular lobule of right cerebellar hemisphere (Fig. 8.11).

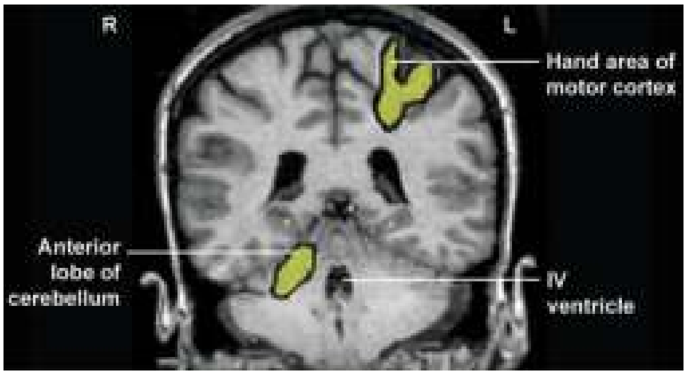

R
L
Hand area of motor cortex
Anterior lobe of cerebellum
IV ventricle

Fig. 8.11: MRI showing activity in left cerebral cortex and right cerebellum on moving the fingers of right hand

Competency:
AN60.3 Describe anatomical basis of cerebellar dysfunction.

CLINICAL NEUROANATOMY

Cerebellar syndrome

It is a group of signs and symptoms produced due to lesion of the cerebellum (Flowchart 8.4). The components of cerebellar syndrome are divided into three sets as follows:

1. Lesion of archicerebellum or flocculonodular lobe (vestibular cerebellum)
2. Lesion of paleocerebellum (spinal cerebellum)
3. Lesion of neocerebellum (cerebral cerebellum)

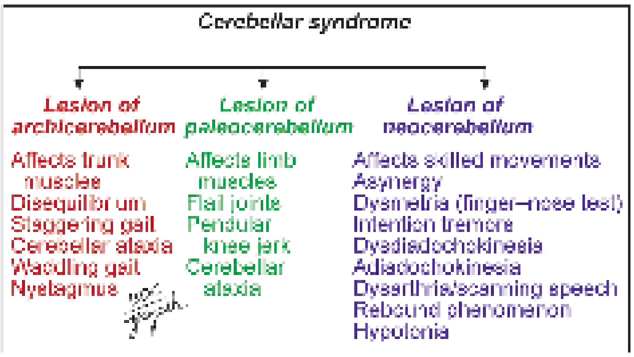
Lesion in flocculonodular lobe or archicerebellum: As the archicerebellum maintains equilibrium, tone, and posture of the *trunk* muscles with the help of inputs from vestibular nuclei, its lesion leads to:

1. *Disequilibrium*: It is characterized by unsteady and *staggering gait*. The patient tends to fall forward, backward, or laterally on standing – this is called *cerebellar ataxia*.
2. *Waddling gait*: The person stands and walks with the legs wide apart.
3. *Nystagmus*: The involuntary to and fro oscillatory movements of the eyeballs while looking to either side.

***Lesion in paleocerebellum* (*spinal cerebellum*):** As the paleocerebellum maintains the tone, posture, and crude movements of the *limbs* by sensory inputs from the spinal cord, its lesion leads to hypotonia and asthenia of limb muscles. It causes:

1. *Flail joints* – lack of joint stability
2. *Pendular knee jerk* – tapping of patellar tendon produces oscillating movements of leg, that is, leg swings backward and forward
3. *Cerebellar ataxia* (= disorderly, Greek) – inability to maintain balance while walking

Flowchart 8.4: Cerebellar syndrome


Cerebellar syndrome
Lesion of archicerebellum
Lesion of paleocerebellum
Lesion of neocerebellum
Affects trunk muscles
Disequilibrium
Staggering gait
Cerebellar ataxia
Waddling gait
Nystagmus
Affects limb muscles
Flail joints
Pendular knee jerk
Cerebellar ataxia
Affects skilled movements
Asynergy
Dysmetria (finger–nose test)
Intention tremors
Dysdiadochokinesia
Adiadochokinesia
Dysarthria/scanning speech
Rebound phenomenon
Hypotonia

***Lesion of neocerebellum* (*cerebral cerebellum*):** As the neocerebellum controls the smooth performance of skilled voluntary movements, its lesion produces the following signs:

1. *Asynergy*: Loss of smooth movements. The movements are intermittent and jerky.
2. *Dysmetria*: Errors in measurement of rates, range, force, and direction of movement.
   Pastpointing (finger–nose test): Inability to touch the nose by finger. The patient overshoots or undershoots the tip of nose.
3. *Intention tremors*: The tremors come on initiation of voluntary movement and disappear during rest.
4. *Dysdiadochokinesia* or *adiadochokinesia*: Inability to perform respect alternating movements, that is, supination and pronation of forearm, tapping of one hand with other hand.
5. *Dysarthria* or *scanning speech*: The muscular incoordination produces slurred, prolonged, explosive speech with pause in wrong place.
6. *Rebound phenomenon*: The patient is unable to stop action suddenly. For example, if patient pushes some object, on sudden removal of the object, the patient is not able to stop the pushing act.
7. *Hypotonia* (diminished muscle tone) results in excess movements of limbs (loose joints or ragdoll appearance).

Note: Lesion of vermis and paravermal zone results to truncal ataxia and nystagmus, abnormal stance, and gait. The l*esion of cerebellar hemisphere* results in ataxia and tremor on the ipsilateral side body. It also produces nystagmus, intention tremor, delayed initiation of motor activity, abnormal stance, and gait, hypotonia, dysarthria, dysmetria, dysdiadochokinesia, dysrhythmias, and rebound phenomenon.

VIDEO

Video 4.6 **Cerebellum**

Facts to Remember

- Cerebellum or a little brain acts like younger sibling of the large cerebrum. It controls tone, posture, equilibrium and fine movements of the body. It cannot initiate the movement.
- It is connected to medulla oblongata by inferior cerebellar peduncle, to pons by middle cerebellar peduncle, and to midbrain by superior cerebellar peduncle.

- Number of neurons are about half of the cerebrum, though it is much smaller than the cerebrum.
- Its structure is uniform throughout, i.e. homotypical. It has outer molecular, middle Purkinje cell layer, and inner granular layer.
- Its control is ipsilateral side of the body.
- *Climbing fibres* are olivocerebellar fibres and *mossy fibres* are other than olivocerebellar fibres reaching to cerebellum.
- Cerebellar nuclei – dentate nucleus, emboliform nucleus, globose nucleus, and nucleus fastigius.

BDC's Anatomy e-book

1. Functional divisions of cerebellum
2. Morphological and functional divisions of cerebellum
3. Constituents of the cerebellar peduncles
4. Development of cerebellum
5. Further reading
6. Viva voce questions

Chapter
9

Fourth Ventricle

Competency:
AN63.1 Describe and demonstrate parts, boundaries and features of IIIrd, IVth and lateral ventricle.

The cavity of hindbrain is called the fourth ventricle. It is a tent-shaped space situated between the pons and upper part of medulla oblongata in front and cerebellum behind. So it lies dorsal to pons and upper part of medulla oblongata and ventral to cerebellum.

It has lateral boundaries, floor, roof and a cavity (Fig. 9.1, Plate 9.1 and Flowchart 9.1) with recesses and angles.

Communication

The cavity of the fourth ventricle communicates inferiorly with the central canal and superiorly with cerebral aqueduct.

Lateral Boundaries of Fourth Ventricle

On each side, fourth ventricle is bounded:

1. Inferolaterally by gracile, cuneate tubercles and inferior cerebellar peduncles.
2. Superolaterally by the superior cerebellar peduncles.

Floor of Fourth Ventricle

It is also called ***'rhomboid fossa'*** because of its rhomboidal shape. The floor is formed by:

1. Posterior (dorsal) surface of lower part of pons (Plate 9.2).
2. Posterior (dorsal) surface of open or upper part of medulla oblongata.

Structural Layers

The floor is lined by:

1. Ependyma
2. A thin layer of the neuroglia beneath the ependyma
3. A layer of grey matter, forming the various nuclei deep to neuroglia.

Parts

It is divisible into:

1. An upper triangular part formed by dorsal surface of pons.

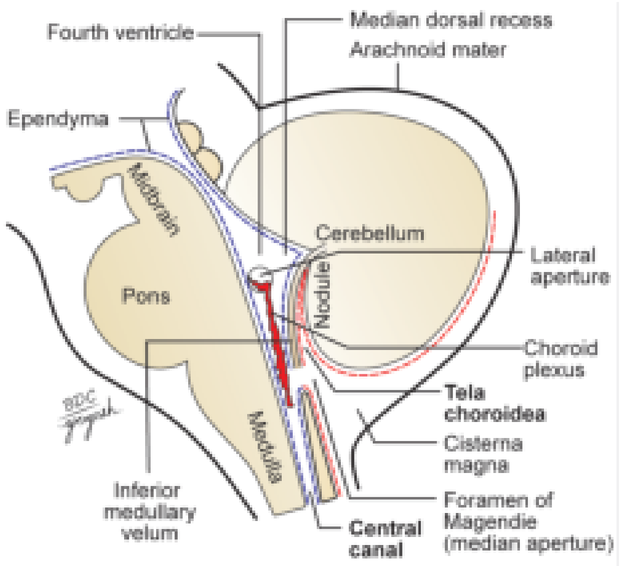


Fig 9.1: Fourth ventricle

2. A lower triangular part formed by dorsal surface of medulla.
3. The intermediate part is at the junction of pons and medulla. The intermediate part is prolonged laterally over the inferior cerebellar peduncle as the floor of lateral recess. This part is marked by transversely running fibres which are fibres of *stria medullaris*. These fibres represent fibres from arcuate nucleus to the opposite cerebellum.

Features of the Floor

1. ***Dorsal median sulcus*** divides the floor into two symmetrical halves.
2. ***Sulcus limitans*** divides each half into median eminence and lateral vestibular area. The sulcus limitans presents depression at the cranial end called superior fovea and towards caudal part called inferior fovea (Fig. 9.2).
3. ***Median eminence*:** The eminence is wider above and narrow below. It presents facial colliculus just opposite and medial to superior fovea. Deep to the colliculus is the genu of the facial nerve formed by this nerve looping around the abducent nucleus.

Plate 9.1: Fourth ventricle (midsagittal section, right medial view)

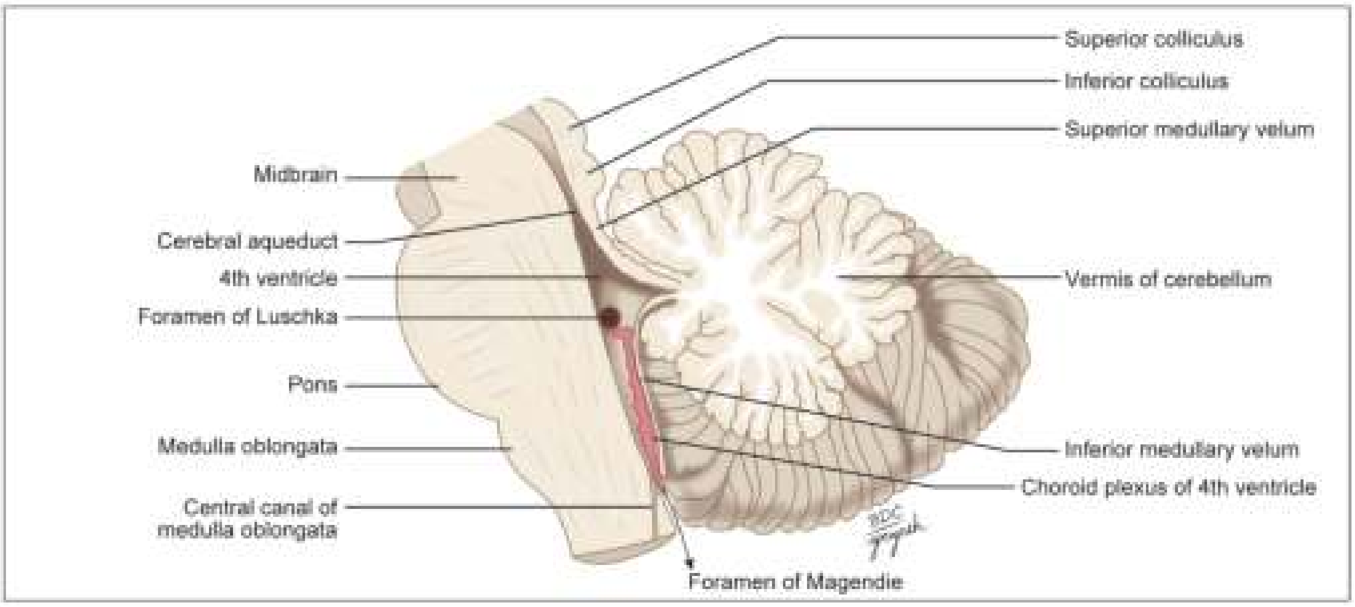
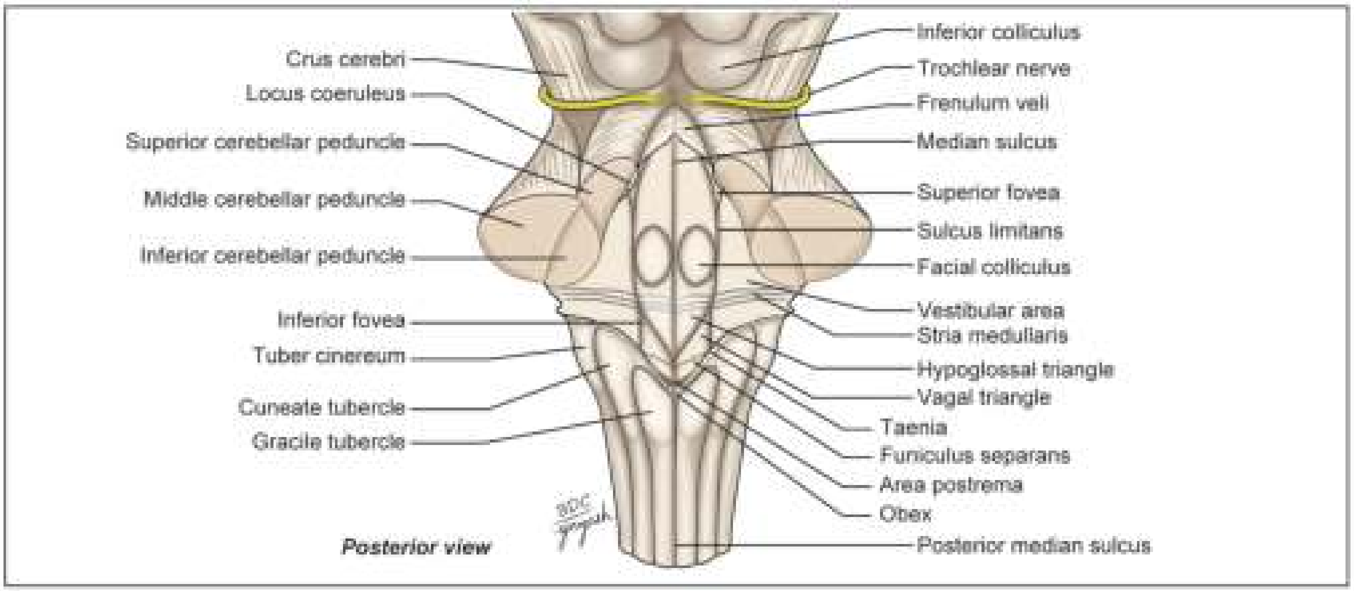
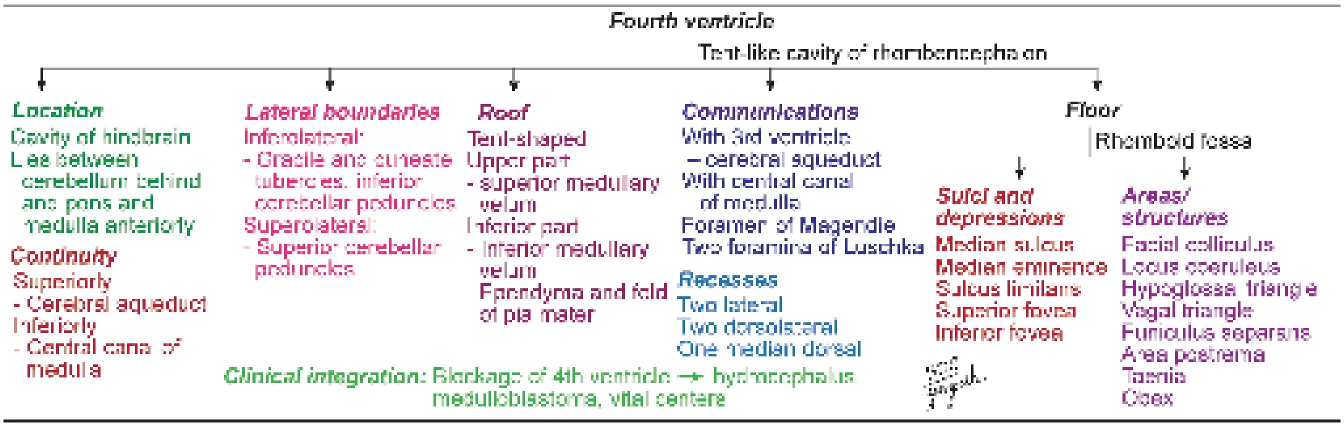

Superior colliculus
Inferior colliculus
Superior medullary velum
Midbrain
Cerebral aqueduct
4th ventricle
Foramen of Luschka
Vermis of cerebellum
Pons
Medulla oblongata
Inferior medullary velum
Choroid plexus of 4th ventricle
Central canal of medulla oblongata
Foramen of Magendie

Plate 9.2: Floor of fourth ventricle


Crus cerebri
Locus coeruleus
Superior cerebellar peduncle
Middle cerebellar peduncle
Inferior cerebellar peduncle
Inferior fovea
Tuber cinereum
Cuneate tubercle
Gracile tubercle
Posterior view
Inferior colliculus
Trochlear nerve
Frenulum veli
Median sulcus
Superior fovea
Sulcus limitans
Facial colliculus
Vestibular area
Stria medullaris
Hypoglossal triangle
Vagal triangle
Taenia
Funiculus separans
Area postrema
Obex
Posterior median sulcus

Flowchart 9.1: Fourth ventricle



Fourth ventricle

Tent-like cavity of rhombencephalon

Location
Cavity of hindbrain
Lies between cerebellum behind and pons and medulla anteriorly

Continuity
Superiorly
- Cerebral aqueduct

Inferiorly
- Central canal of medulla

Lateral boundaries
Inferolateral:
- Gracile and cuneate tubercles, inferior cerebellar peduncles

Superolateral:
- Superior cerebellar peduncles

Roof
Tent-shaped
Upper part
- superior medullary velum

Inferior part
- Inferior medullary velum
- Ependyma and fold of pia mater

Communications
With 3rd ventricle – cerebral aqueduct
With central canal of medulla
Foramen of Magendie
Two foramina of Luschka

Recesses
Two lateral
Two dorsolateral
One median dorsal

Floor
Rhomboid fossa

Sulci and depressions
Median sulcus
Median eminence
Sulcus limitans
Superior fovea
Inferior fovea

Areas/ structures
Facial colliculus
Locus coeruleus
Hypoglossal triangle
Vagal triangle
Funiculus separans
Area postrema
Taenia
Obex

Clinical integration: Blockage of 4th ventricle → hydrocephalus medulloblastoma, vital centers

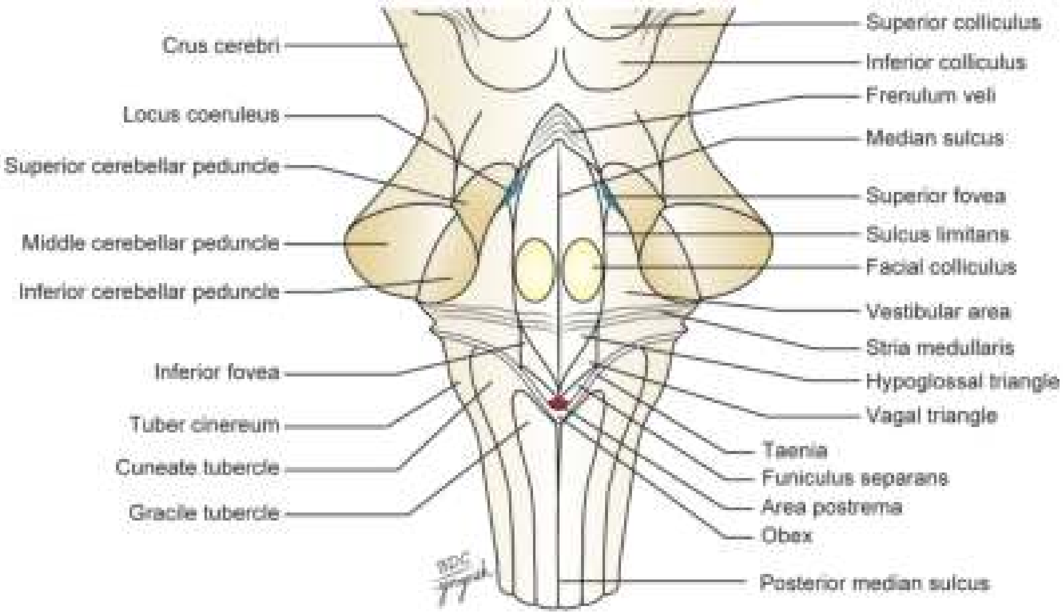

Crus cerebri
Locus coeruleus
Superior cerebellar peduncle
Middle cerebellar peduncle
Inferior cerebellar peduncle
Inferior fovea
Tuber cinereum
Cuneate tubercle
Gracile tubercle
Superior colliculus
Inferior colliculus
Frenulum veli
Median sulcus
Superior fovea
Sulcus limitans
Facial colliculus
Vestibular area
Stria medullaris
Hypoglossal triangle
Vagal triangle
Taenia
Funiculus separans
Area postrema
Obex
Posterior median sulcus

Fig. 9.2: Floor of fourth ventricle

4. In the uppermost part (pontine part), the sulcus limitans overlies an area that is bluish in colour and is called ***locus coeruleus***. The colour is due to presence of pigmented neurons which constitute ***substantia ferruginea***. These neurons belong to the reticular formation. They are rich in noradrenaline and help in paradoxical sleep.
5. Descending from the inferior fovea, there is a sulcus that runs obliquely towards midline. This sulcus divides median eminence into two triangles. These are ***hypoglossal triangle*** medially and ***vagal triangle*** laterally. These overlie the hypoglossal nerve nucleus and of vagus nerve, respectively.
6. Between the vagal triangle above and gracile tubercle below, there is small area called the ***area postrema*** which may function as chemoreceptor. An ependymal thickening called ***funiculus separans*** separates both. This area is devoid of blood–brain barrier.
7. ***Vestibular area*:** This lies lateral to the inferior fovea (sulcus limitans) which overlies the vestibular nuclei. This area is partly in the pons and partly in the medulla.

Note: The lowest part of the floor resembles the pointed nib of writing pen so it is described as calamus scriptorius.

Roof of Fourth Ventricle

The roof of the ventricle is diamond-shaped and can be divided into superior and inferior parts (Fig. 9.3).

1. The superior or cranial part of roof is formed by superior cerebellar peduncles and superior medullary velum. The superior cerebellar peduncles on emerging from central white matter of cerebellum pass first cranially and ventrally forming at first lateral boundaries of ventricles. On approaching the inferior colliculi, they converge and then intermingle over the ventricles and form part of the roof.

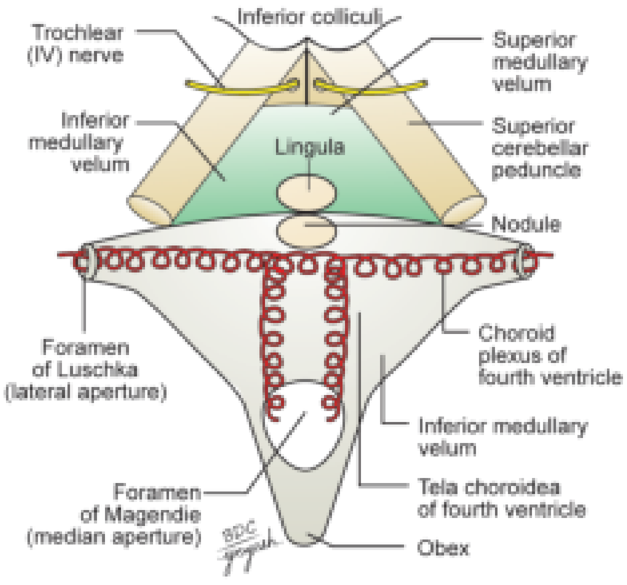

Trochlear (IV) nerve
Inferior colliculi
Superior medullary velum
Inferior medullary velum
Lingula
Superior cerebellar peduncle
Nodule
Foramen of Luschka (lateral aperture)
Choroid plexus of fourth ventricle
Inferior medullary velum
Foramen of Magendie (median aperture)
Tela choroidea of fourth ventricle
Obex

Fig. 9.3: Roof of fourth ventricle

Superior medullary velum (white matter) lies in between the two superior cerebellar peduncles. It is triangular in shape. Frenulum veli is a vertical ridge on the posterior surface of superior medullary velum. Trochlear, the 4th cranial nerve, emerges on each side of this ridge.

2. The lower part of roof is also sloping like the upper part. It is formed by fold of pia mater and ependyma of the ventricle. Laterally, it is formed by semilunar inferior medullary velum. Its outer surface is covered by fold of pia mater, while inner surface is covered by ependyma. It gets continuous with white matter of cerebellum. Two narrow bands of white matter extend down from inferior medullary velum to form lower part of roof of ventricle called the obex.

Openings in the Roof

In the caudal part of roof of fourth ventricle, there are three openings—one median and two lateral (Fig. 9.3).

1. The median aperture of fourth ventricle, alternatively known as ***foramen of Magendie,*** is a large opening situated caudal to nodule. This opening provides the principal communication between ventricular system and subarachnoid space.
2. The lateral apertures, also known as ***foramina of Luschka***, are situated at the ends of lateral recesses and are partly occupied by parts of choroid plexuses which protrude into subarachnoid space. Through these also fourth ventricle communicates with subarachnoid space.

Tela Choroidea of Fourth Ventricle

Tela choroidea of 4th ventricle is a fold (double layer) of pia mater with capillaries. This fold enters 4th ventricle in the interval between lower part of roof of the ventricle and the cerebellum.

Choroid Plexuses of Fourth Ventricle

The fold of pia mater with capillaries lined by secretory ependyma forms the choroid plexus. This plexus is "T-shaped", the vertical limbs are two in number, lie side by side, reach the median aperture and project into subarachnoid space through it. The horizontal limbs on each side extend into the lateral recesses. The arterial supply for the plexuses is from posterior inferior cerebellar arteries.

Angles of Fourth Ventricle

Superior angle: Continuous with cerebral aqueduct.

Inferior angle: Continuous below with central canal of spinal cord.

Lateral angles: One on each side towards the inferior cerebellar peduncles.

Cavity and Recesses of Fourth Ventricle

The cavity lies between roof and floor of the ventricle. It reveals some recesses. These are extensions of the main cavity of ventricle. Five recesses have been identified (Fig. 9.4).

1. Two lateral recesses—one on each side. Each lateral recess passes laterally in the interval between the inferior cerebellar peduncle (ventrally) and the peduncle of flocculus dorsally reaching as far as the medial part of flocculus.
2. One recess present in the median plane, is known as median dorsal recess. It extends dorsally into white core of cerebellum and lies above the cerebellar nodule (Fig. 9.5).
3. Two lateral dorsal recesses—one on each side. Each lateral dorsal recess extends dorsally lateral to the nodule and cranial to the inferior medullary velum. These lie on either side of median dorsal recess.

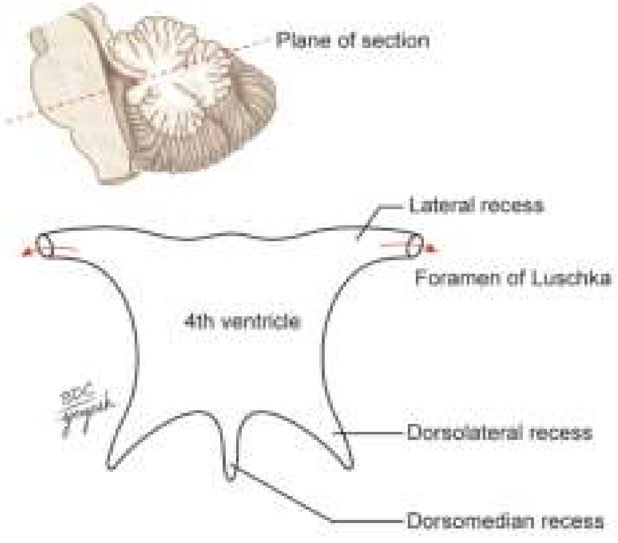


Fig. 9.4: Recesses and apertures of the fourth ventricle

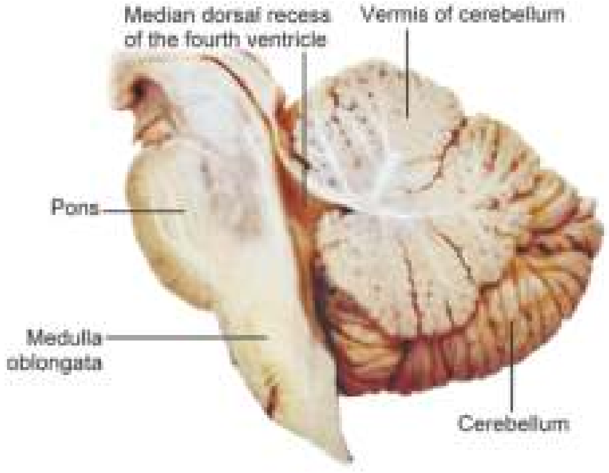


Fig. 9.5: Median dorsal recess of the fourth ventricle

CLINICAL NEUROANATOMY

- ***Vital centres*** are situated in the vicinity of vagal triangle. An injury to this area, therefore, would prove fatal.
- ***Hydrocephalus*** is a condition that occurs due to abnormal increase in CSF within the ventricle system. It may occur due to occlusion of outflowing channels of CSF (ventricle → subarachnoid space → dural venous sinuses). Sometimes, the foramen of Magendie or foramen of Luschka may get occluded due to growing tumours or fibrous adhesions after meningitis. It may produce hydrocephalus, headache, vomiting, papilloedema, etc.
- ***Medulloblastoma***: It is the most common tumour in the region of 4th ventricle. It arises from poorly differentiated primitive neuroectodermal cells of cerebellar vermis.
- The 4th ventricle can be visualised in MRI (Fig. 9.6).

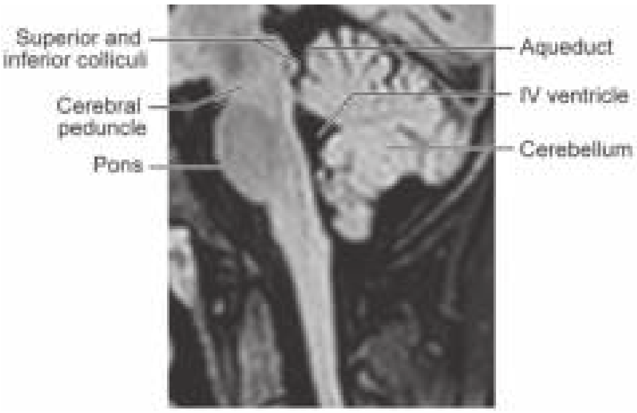

Superior and inferior colliculi
Cerebral peduncle
Pons
Aqueduct
IV ventricle
Cerebellum

Fig. 9.6: MRI showing fourth ventricle

Facts to Remember

- Vital centres like respiratory and cardiovascular are situated in the floor of fourth ventricle.
- Fourth ventricle has 3 openings, one foramen of Magendie and two foramina of Luschka for the exit of used CSF into the subarachnoid space for absorption in the superior sagittal venous sinus.
- It also has 5 recesses to accommodate the CSF.
- In its floor are nuclei of VI, VII, VIII, X and XII cranial nerves.

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1. Further reading
2. Viva voce questions

Chapter

10

Diencephalon and Third Ventricle

DIENCEPHALON

The diencephalon is a middle structure which is largely embedded in the cerebrum, and, therefore, hidden from surface view. Its cavity forms the greater part of the third ventricle. The hypothalamic sulcus, extending from the interventricular foramen to the cerebral aqueduct, divides each half of the diencephalon into dorsal and ventral parts (Plate 10.1).

The diencephalon consists of pairs of:

1. Thalamus
2. Hypothalamus
3. Metathalamus: Medial geniculate body (MGB), lateral geniculate body (LGB)
4. Subthalamus
5. Epithalamus: Pineal body, habenular nuclei and commissure, posterior commissure, and stria medullaris thalami.

Competency:

AN62.5 Describe boundaries, parts, gross relations, major nuclei and connections of dorsal thalamus, hypothalamus, epithalamus, metathalamus and subthalamus.

THALAMUS

The thalamus (Greek *inner chamber*) is a large mass of grey matter 4 cm each in transverse, vertical and anteroposterior diameters situated in the lateral wall of the third ventricle and the floor of the central part of the lateral ventricle (Figs 10.1 to 10.5 and Flowchart 10.1).

Major Functions of Thalamus

1. *Sensory relay station*: Thalamus is a sensory station for all impulses except olfactory sensation.
2. *Pain and temperature perception*: Thalamus is capable of poor recognition of pain and temperature sensations.
3. *Extrapyramidal function*: It conveys sensory inputs of cerebellum and basal ganglia to motor cortex and influences motor activity.
4. *Maintenance of wakefulness and alertness* through influencing ascending reticular activating system.
5. *Emotional behavior and recent memory*: These play a role as a part of limbic system in emotional behaviour and recent memory mechanism.
6. *Autonomic control of viscera*: It takes part in autonomic control through the hypothalamus.
7. Mood and emotional balance.
8. Personality and intellect of an individual.

External Features of Thalamus

Measurements

- Length (anteroposterior): 4 cm
- Vertical: 1.5 cm
- Width (transverse): 1.5 cm.

Flowchart 10.1: Thalamus

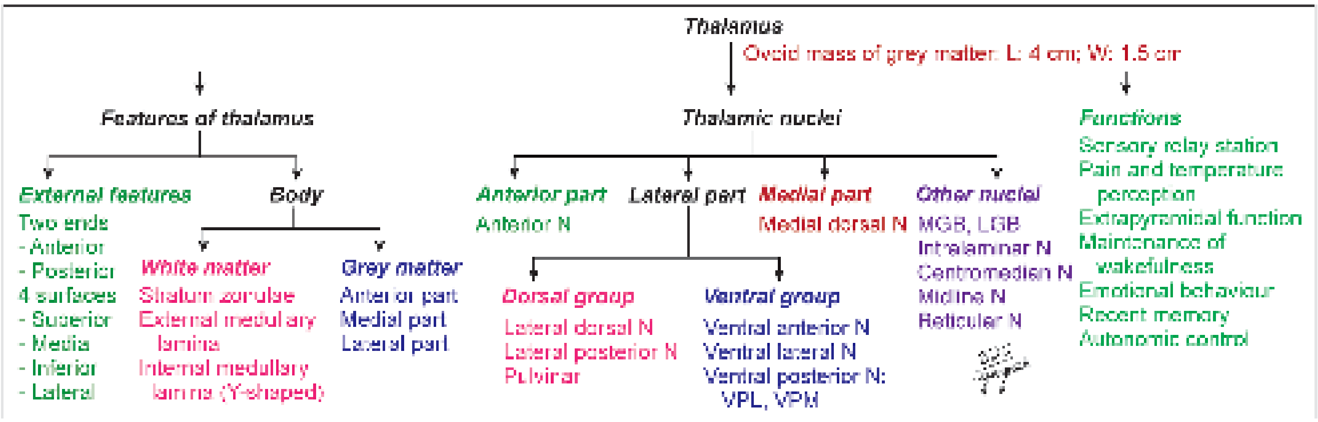
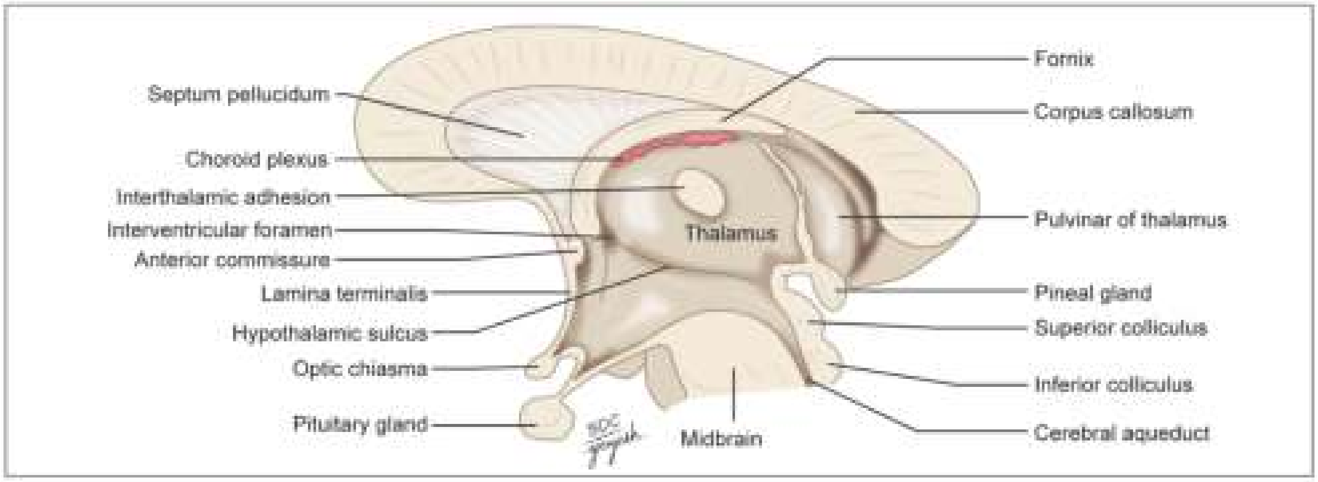

Thalamus
Ovoid mass of grey matter: L: 4 cm; W: 1.5 cm
Features of thalamus
External features
Two ends
- Anterior
- Posterior
4 surfaces
- Superior
- Medial
- Inferior
- Lateral
Body
White matter
Stratum zonale
External medullary lamina
Internal medullary lamina (Y-shaped)
Grey matter
Anterior part
Medial part
Lateral part
Thalamic nuclei
Anterior part
Anterior N
Lateral part
Dorsal group
Lateral dorsal N
Lateral posterior N
Pulvinar
Ventral group
Ventral anterior N
Ventral lateral N
Ventral posterior N: VPL, VPM
Medial part
Medial dorsal N
Other nuclei
MGB, LGB
Intralaminar N
Centromedian N
Midline N
Reticular N
Functions
Sensory relay station
Pain and temperature perception
Extrapyramidal function
Maintenance of wakefulness
Emotional behaviour
Recent memory
Autonomic control

Plate 10.1: Location of diencephalon (sagittal section of the brain)


Septum pellucidum
Choroid plexus
Interthalamic adhesion
Interventricular foramen
Anterior commissure
Lamina terminalis
Hypothalamic sulcus
Optic chiasma
Pituitary gland
Thalamus
Midbrain
Fornix
Corpus callosum
Pulvinar of thalamus
Pineal gland
Superior colliculus
Inferior colliculus
Cerebral aqueduct

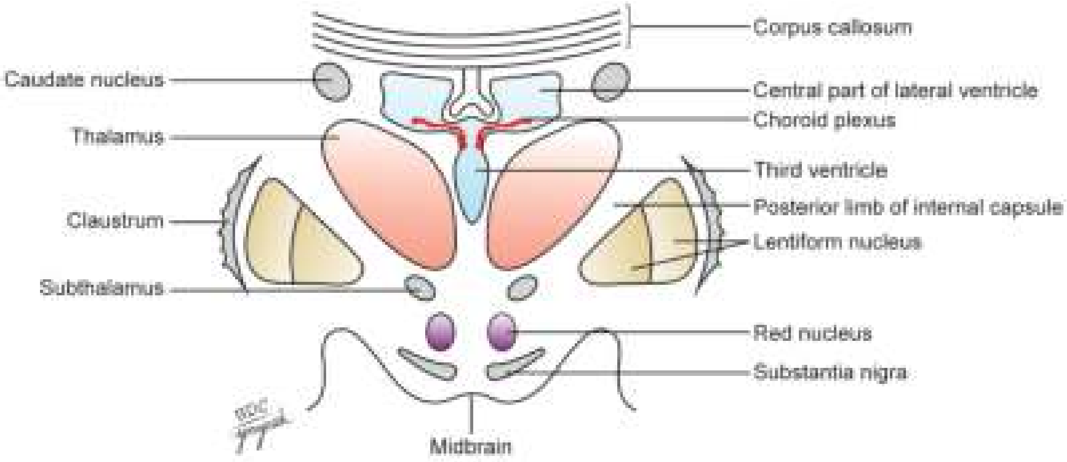

Caudate nucleus
Thalamus
Claustrum
Subthalamus
Midbrain
Corpus callosum
Central part of lateral ventricle
Choroid plexus
Third ventricle
Posterior limb of internal capsule
Lentiform nucleus
Red nucleus
Substantia nigra

Fig. 10.1: Relations of thalamus (posterior view, coronal section of the brain)

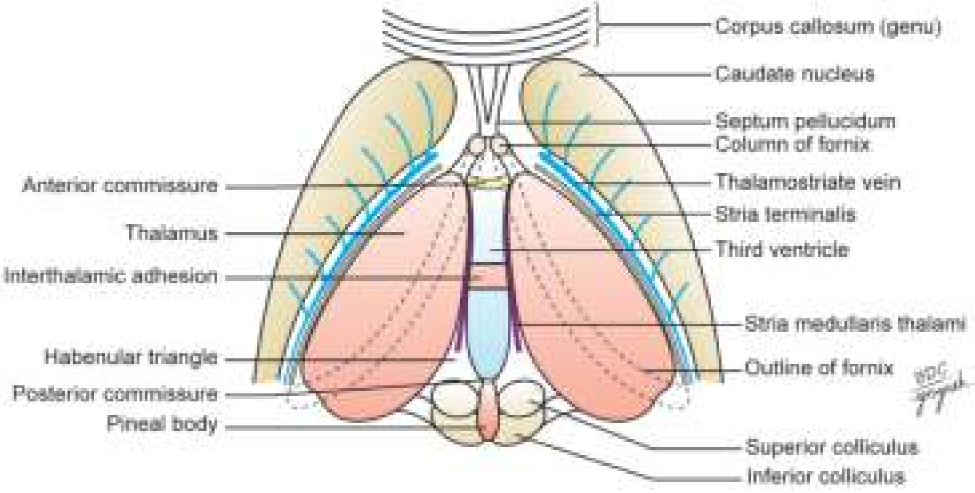

Anterior commissure
Thalamus
Interthalamic adhesion
Habenular triangle
Posterior commissure
Pineal body
Corpus callosum (genu)
Caudate nucleus
Septum pellucidum
Column of fornix
Thalamostriate vein
Stria terminalis
Third ventricle
Stria medullaris thalami
Outline of fornix
Superior colliculus
Inferior colliculus

Fig. 10.2: Relation of thalamus with third ventricle (superior view, *Note*: overlying tela choroidea of third ventricle is removed)

Each thalamus has

- Two ends: Anterior and posterior
- Four surfaces: Superior, inferior, medial, and lateral.

Ends

1. ***Anterior end*** with anterior nucleus is narrow and forms the posterior boundary of the interventricular foramen.
2. ***Posterior end*** is expanded and is known as the ***pulvinar.*** It overhangs the lateral and medial geniculate bodies, and the superior colliculus with its brachium.

Surfaces

1. ***Superior surface*** is divided into:
    a. A lateral ventricular part which forms the floor of the central part of the lateral ventricle

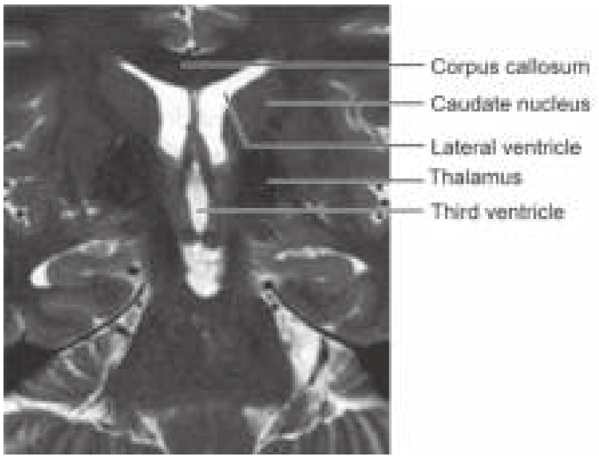
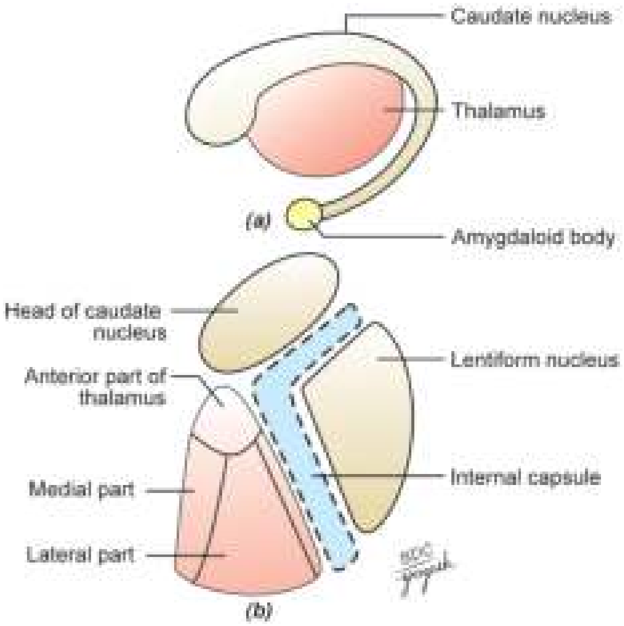

Corpus callosum
Caudate nucleus
Lateral ventricle
Thalamus
Third ventricle

Fig. 10.3: MRI of thalamus


Caudate nucleus
Thalamus
(a)
Amygdaloid body
Head of caudate nucleus
Anterior part of thalamus
Lentiform nucleus
Medial part
Internal capsule
Lateral part
(b)

Figs 10.4a and b: (a) Lateral view of thalamus and caudate nucleus and (b) thalamus as seen in horizontal section

   b. A medial extraventricular part which is covered by the tela choroidea of the 3rd ventricle.
2. ***Inferior surface*** rests on the subthalamus and the hypothalamus.
3. ***Medial surface*** forms the posterosuperior part of the lateral wall of the third ventricle. The medial surfaces of two thalami are interconnected by an interthalamic adhesion.
4. ***Lateral surface*** forms the medial boundary of the posterior limb of the internal capsule.

Note: Superior surface thalamus is related to the body of the caudate nucleus laterally. *Stria terminalis* and *thalamostriate vein* run between the thalamus and caudate nucleus.

Stria medullaris thalami separates superior surface from medial surface of thalamus.

Taenia thalami is a line of reflection of ependyma of 3rd ventricle from its lateral wall to its roof.

Internal Structure of Thalamus

The thalamus is mainly consisting of grey matter and a thin layer of white matter.

White Matter

The thalamus contains small quantity of white matter as the following thin laminae:

1. *Stratum zonulae* on the superior surface
2. *External medullary lamina* on the lateral surface
3. *Internal medullary lamina* lies within the thalamus.

The *internal medullary lamina* is a vertical sheet of Y-shaped white matter that bifurcates anterosuperiorly.

Grey Matter

The Y-shaped internal medullary lamina divides the thalamus into anterior, medial, and lateral parts. The anterior part lies between the limbs of the 'Y' and medial and lateral parts on either side of the stem of 'Y'. The grey matter of the thalamus consists of number of nuclei as follows:

1. *Anterior nucleus* in the anterior part (Fig. 10.5).
2. *Medial nucleus* in the medial part.
3. The lateral part of the thalamus is the largest and represents the *neothalamus*. It is divided into:
   a. *Lateral nucleus* in the dorsolateral part
   b. *Ventral nucleus* in the ventromedial part. The ventral nucleus is subdivided into anterior, intermediate and posterior groups. The posterior

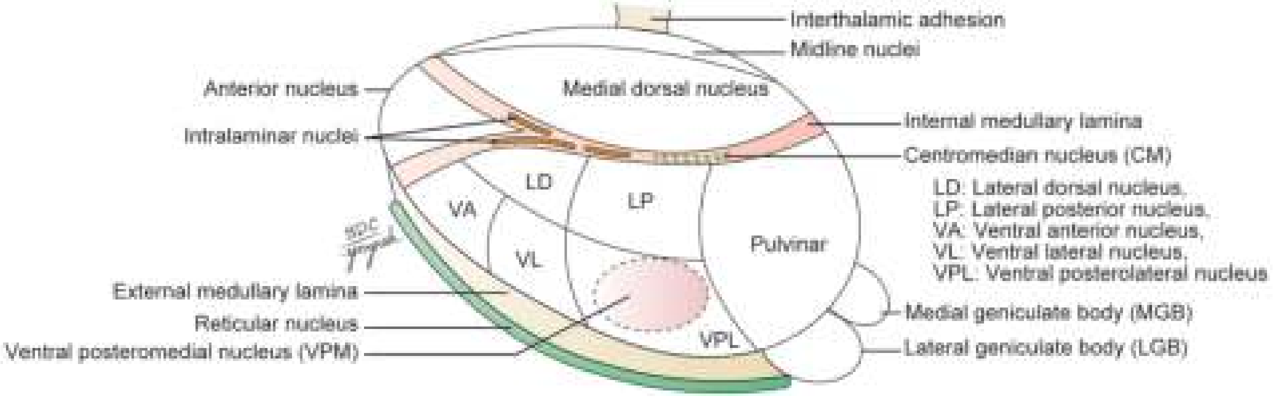

Interthalamic adhesion
Midline nuclei
Anterior nucleus
Medial dorsal nucleus
Intralaminar nuclei
Internal medullary lamina
Centromedian nucleus (CM)
LD
LP
VA
VL
Pulvinar
VPL
External medullary lamina
Reticular nucleus
Ventral posteromedial nucleus (VPM)
Medial geniculate body (MGB)
Lateral geniculate body (LGB)
LD: Lateral dorsal nucleus,
LP: Lateral posterior nucleus,
VA: Ventral anterior nucleus,
VL: Ventral lateral nucleus,
VPL: Ventral posterolateral nucleus

Fig. 10.5: Thalamic nuclei (schematic representation, note: Centromedian nucleus and VPM nucleus lies deep)

group is further subdivided into the posterolateral and posteromedial groups.

4. *Intralaminar nuclei* including *centromedian nucleus* (located in the internal medullary lamina), midline nuclei (periventricular grey on the medial surface) and reticular nuclei (on the lateral surface) are also present. The *medial geniculate body* (*MGB*) and *lateral geniculate body* (*LGB*) are also considered as a part of thalamus which forms metathalamus.

The thalamic nuclei are listed in Table 10.1 (Fig. 10.6) and their major connections and functions are given in Table 10.2. Medial and lateral geniculate bodies are described below separately.

TABLE 10.1: Thalamic nuclei

Part	***Nuclei***
Anterior part	Anterior nucleus
Medial part	Medial dorsal nucleus (only one in humans)
Lateral part	
1. Dorsal tier nuclei	Lateral dorsal nucleus Lateral posterior nucleus Pulvinar
2. Ventral tier nuclei	Ventral anterior nucleus Ventral lateral nucleus Ventral posterior nucleus: Ventral posterolateral (VPL) and ventral posteromedial (VPM)
Other nuclei	Medial geniculate body (MGB) Lateral geniculate body (LGB) Intralaminar nuclei Centromedian nucleus (CM) Midline nuclei Reticular nucleus

CLINICAL NEUROANATOMY

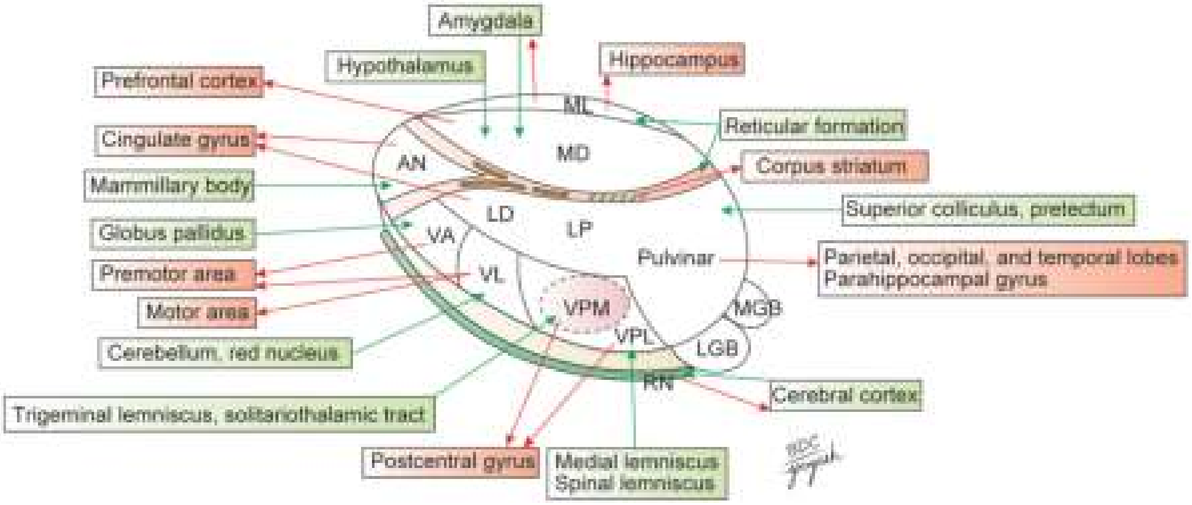
- ***Thalamic syndrome:*** A vascular lesions of thalamogeniculate branch of posterior cerebral artery results in thalamic syndrome. It is characterized by the following features:
  1. Hyperesthesia – exaggerated sensations.
  2. Severe spontaneous pain on the opposite side of body.
  3. Emotional instability, that is, patient may laugh or cry without any reason.
  4. *Thalamic phantom limb*, that is, patient is unable to locate the limb with the eyes closed and develops the illusion that the limb is lost.
  5. *Thalamic hand*: It may occur in thalamic lesions. The opposite hand is involved. The forearm is pronated, wrist flexed, metacarpophalangeal joint flexed, and interphalangeal joint extended.
- ***Thalamic pain syndrome* (*Dejerine-Roussy syndrome*):** It involves loss of sensation followed by progressive agonizing pain in the parts of body where loss of sensation has occurred. It shows:
  a. *Allodynia* – a painful sensation elicited from an innocuous stimulus on normal skin
  b. *Hyperpathia* – an unusual and intense response to nociceptive stimuli
  c. *Dysesthesia* – an abnormal sensation triggered by sense of touch.

METATHALAMUS

The metathalamus consists of the medial and lateral geniculate bodies, which are situated on each side of the midbrain, below the thalamus (Plate 10.2 and Flowchart 10.2).

Medial Geniculate Body (MGB)

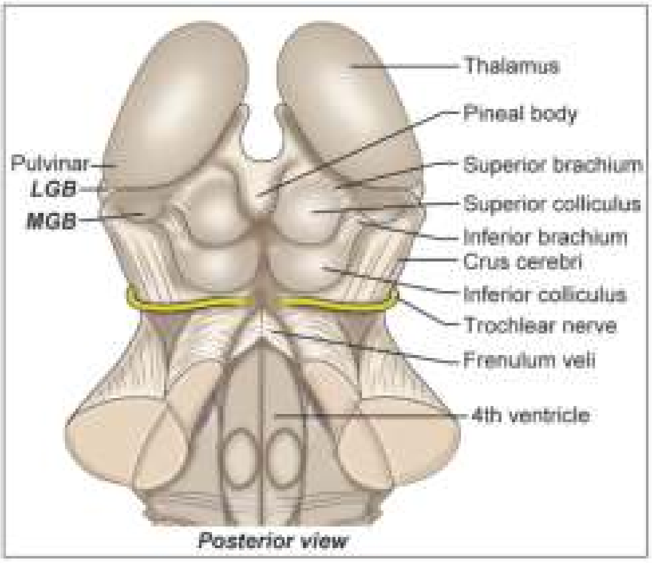
It is an oval elevation situated just below the pulvinar of the thalamus and lateral to the superior colliculus. The



Amygdala
Hypothalamus
Hippocampus
Prefrontal cortex
ML
Reticular formation
Cingulate gyrus
MD
AN
Corpus striatum
Mammillary body
LD
Superior colliculus, pretectum
LP
Globus pallidus
VA
Pulvinar
Parietal, occipital, and temporal lobes
Parahippocampal gyrus
Premotor area
VL
Motor area
VPM
MGB
VPL
Cerebellum, red nucleus
LGB
RN
Cerebral cortex
Trigeminal lemniscus, solitariothalamic tract
Postcentral gyrus
Medial lemniscus
Spinal lemniscus

Fig. 10.6: Major afferent connections of the thalamus (schematic representation, green arrows – afferent fibres and red arrows – efferent fibres)

Plate 10.2: Geniculate bodies (posterior view of brainstem)



inferior brachium connects the medial geniculate body to the inferior colliculus. The connections of the medial geniculate body are as follows:

Afferents

1. Lateral lemniscus
2. Fibres from both inferior colliculi
3. Ascending reticular pathway and perception of painful and nociceptive stimuli.

Efferents

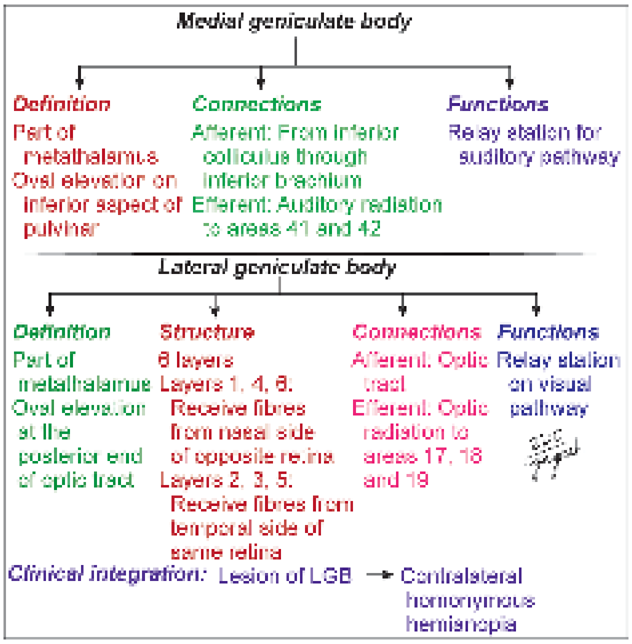
1. It gives rise to the acoustic (auditory) radiation going to the auditory area of the cortex (in the temporal lobe) through the sublentiform part of the internal capsule.
2. To secondary somatosensory area.

Function: Medial geniculate body is the last relay station on the pathway of auditory impulses to the cerebral cortex and for perception of painful and nociceptive stimuli.

TABLE 10.2: Connections and functions of thalamic nuclei

Nucleus	*Afferent*	*Efferent*	*Functions*
Anterior nucleus	From mammillary body (mammillothalamic tract)	To cingulate gyrus	Associate with limbic system Emotional behaviour, recent memory
Medial dorsal nucleus	From hypothalamus, amygdala, other thalamic nuclei	Prefrontal cortex	Association or integration of visceral and somatic activities Personality of individual mood and feelings
Lateral dorsal group (LD, LP, pulvinar)	Ventral thalamic nuclei, superior colliculus, pretectum	Cingulate gyrus, parahippocampal gyrus, parietal, occipital, and temporal lobes	Forms part of limbic system Helps in sensory analysis
Ventral posteromedial nucleus (VPM)	Trigeminal lemniscus Solitariothalamic tract	Postcentral gyrus	Relay station for pain, temperature, touch, proprioceptive sensations from head and face
Ventral posterolateral nucleus (VPL)	Medial lemniscus Spinal lemniscus	Postcentral gyrus	Relay station for pain, temperature, touch, proprioceptive sensations from whole body except face and head
Ventral anterior (VA) nucleus	Globus pallidus through subthalamic fasciculus	Premotor area	Relay station for striatal impulses Modifies motor activity
Ventral lateral (VL) nucleus	Cerebellum (dentatothalamic) Red nucleus (dentato-rubrothalamic)	Motor and premotor areas Influences motor activity	Relay station for cerebellar impulses
Intralaminar nuclei (centromedian and parafascicular nuclei)	Reticular formation	Other thalamic nuclei and corpus striatum	General awareness of painful stimuli Sensory motor integration Maintenance of arousal
Midline nuclei	Reticular formation	Hippocampus, amygdala	Part of limbic system Memory Arousal responses
Thalamic reticular nucleus (lies between external medullary lamina and internal capsule)	Corticothalamic fibres	Other nuclei of thalamus Thalamocortical fibres	Regulation of interthalamic activity
Medial geniculate body	Auditory fibres from inferior colliculus	Primary auditory areas 41, 42	Relay station for auditory impulses and perception of painful and nociceptive stimuli
Lateral geniculate body	Optic tract	Primary visual cortex area 17	Relay station for visual impulses

Flowchart 10.2: Medial and lateral geniculate bodies



Medial geniculate body

Definition
- Part of metathalamus
- Oval elevation on inferior aspect of pulvinar

Connections
- Afferent: From inferior colliculus through inferior brachium
- Efferent: Auditory radiation to areas 41 and 42

Functions
- Relay station for auditory pathway

Lateral geniculate body

Definition
- Part of metathalamus
- Oval elevation at the posterior end of optic tract

Structure
- 6 layers
- Layers 1, 4, 6: Receive fibres from nasal side of opposite retina
- Layers 2, 3, 5: Receive fibres from temporal side of same retina

Connections
- Afferent: Optic tract
- Efferent: Optic radiation to areas 17, 18 and 19

Functions
- Relay station on visual pathway

Clinical integration: Lesion of LGB → Contralateral homonymous hemianopia

Lateral Geniculate Body (LGB)

It is a small oval elevation situated anterolateral to the medial geniculate body, below the thalamus. It is overlapped by the medial part of the temporal lobe, and is connected to the superior colliculus by the superior brachium (Fig. 10.7).

Structure: It is six-layered structure. Layers 1, 4 and 6 receive contralateral optic fibres, and layers 2, 3 and 5 receive ipsilateral optic fibres.

Connections

1. *Afferents:* Optic tract (lateral root).
2. *Efferents:* It gives rise to optic radiations going to the visual area of cortex through retrolentiform part of internal capsule.

Function: Lateral geniculate body is the last relay station on the visual pathway to the occipital cortex.

EPITHALAMUS

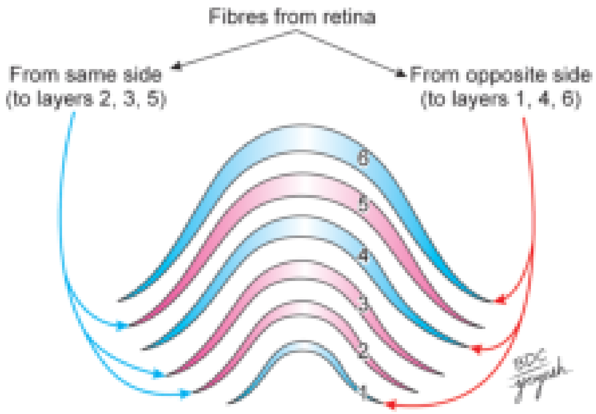
The epithalamus (Fig. 10.8 and Flowchart 10.3) occupies the caudal part of the roof of the diencephalon and consists of:

1. Pineal body or epiphysis cerebri.
2. Right and left habenular nuclei, each situated beneath the floor of the corresponding habenular trigone.
3. Habenular commissure lies superior to suprapineal recess.
4. Posterior commissure lies inferior to the suprapineal recess.

Pineal Body/Pineal Gland

The pineal (Latin *pine, cone*) body is a small, conical organ, projecting backwards and downwards between the two superior colliculi. It is placed below the splenium of the corpus callosum, but is separated from it by the tela choroidea of the third ventricle.

Weight: About 100–200 mg.



Fibres from retina
From same side (to layers 2, 3, 5)
From opposite side (to layers 1, 4, 6)
6
5
4
3
2
1

Fig. 10.7: Six layers of lateral geniculate body

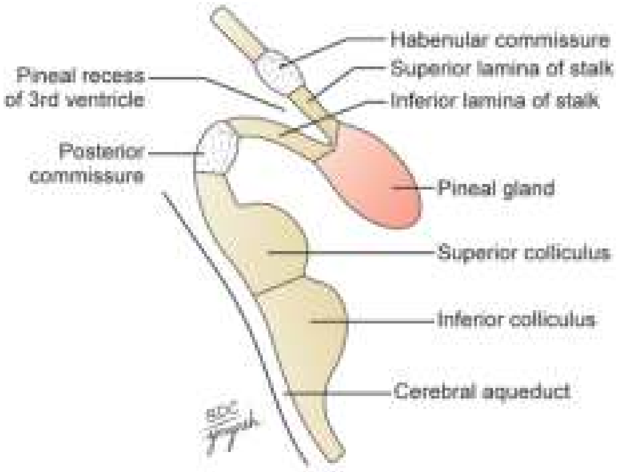
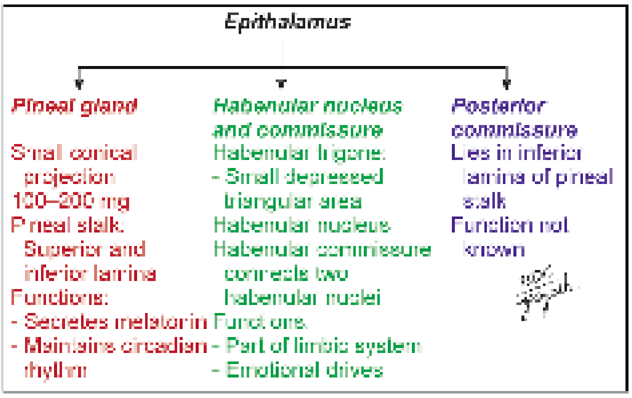


Fig. 10.8: Components of the epithalamus

Flowchart 10.3: Epithalamus



Epithalamus

Pineal gland
- Small conical projection
- 100–200 mg
- Pineal stalk: Superior and inferior lamina
- Functions:
  - Secretes melatonin
  - Maintains circadian rhythm

Habenular nucleus and commissure
- Habenular trigone:
  - Small depressed triangular area
- Habenular nucleus
- Habenular commissure connects two habenular nuclei
- Functions:
  - Part of limbic system
  - Emotional drives

Posterior commissure
- Lies in inferior lamina of pineal stalk
- Function not known

It consists of a conical *body* about 8 mm long, and a *stalk* or *peduncle* which divides anteriorly into two laminae separated by the pineal recess of the 3rd ventricle. The superior lamina of the stalk contains the habenular commissure; and the inferior lamina contains the posterior commissure.

Note: ***Morphological significance:*** In many reptiles, the epiphysis cerebri is represented by a double structure. The anterior part *(parapineal organ)* develops into the pineal or parietal eye. The posterior part is glandular in nature. The human pineal body represents the persistent posterior glandular part only. The parietal eye has disappeared.

Structure: Pineal gland consists of pinealocytes and interstitial cells. The pinealocytes are chief cells of pineal gland. They secrete ***melatonin*** hormone. The interstitial cells are a few cells that support the pinealocytes.

Corpora arenacea or brain sand: It is a characteristic feature of pineal gland. It is a calcified concretion (deposit) that increases with age.

Functions:

1. Secretion of melatonin that inhibits secretion of gonadotropins from hypothalamus.
2. Maintenance of circadian rhythm (*biological clock*).

Habenular Nucleus

The nucleus lies beneath the floor of the habenular trigone (*habenula* = little rein, in Latin). The trigone is a small, depressed triangular area, situated above the superior colliculus and medial to the pulvinar of the thalamus. Medially, it is bounded by the stria medullaris thalami and stalk of the pineal body. The habenular nucleus forms a part of the limbic system.

Afferents

- Hypothalamus
- Amygdaloid body
- Hippocampus

Efferents: To interpeduncular nucleus.

Functions: Acts as nodal point for convergence of basic emotional drives.

Habenular Commissure

These are the fibres that connect the habenular nucleus of two sides across the midline. They lie in the superior lamina of pineal stalk. They form a part of limbic system and are responsible for primitive visceral response to basic emotional drives.

Posterior Commissure

It is a bundle of fibres that cross the midline in the inferior lamina of pineal stalk. It contains fibres from medial longitudinal bundle, interstitial nuclei, and many other adjacent areas. Its exact function is not listed.

Note: ***Stria medullaris thalami*** is a bundle of fibres lying deep to taenia thalami (ependyma of 3rd ventricle). It lies along the junction of medial and superior surfaces of thalamus. It connects the septal nucleus, basal nuclei of Meynert and hypothalamus with habenular nucleus and thus forms a part of limbic system.

HYPOTHALAMUS

The hypothalamus is a part of the diencephalon (Figs 10.9a and b and Flowchart 10.4). It lies in the floor and lateral wall of the third ventricle. It has been designated as the head ganglion of the autonomic nervous system because it takes part in the control of many visceral and metabolic activities of the body.

Anatomically, it includes:

a. The floor of the third ventricle, or structures in the interpeduncular fossa.
b. The lateral wall of the third ventricle below the hypothalamic sulcus.

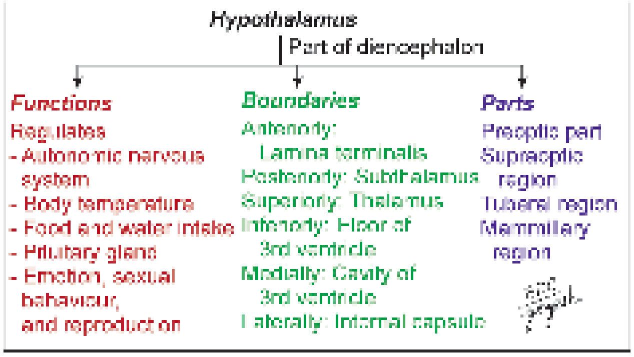
Weight: 4 g (forms less than 1% of total brain weight).

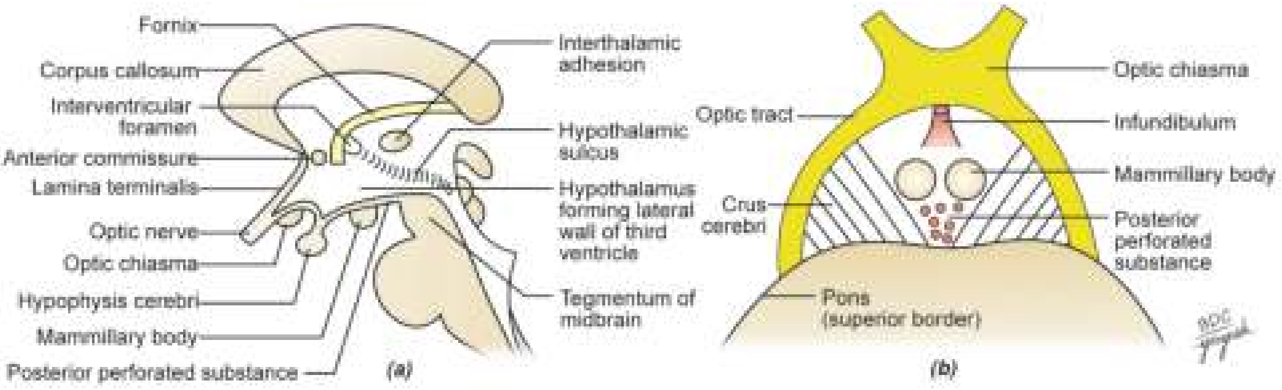
Boundaries

Anteriorly: Lamina terminalis
Posteriorly: Subthalamus
Superiorly: Thalamus
Inferiorly: Floor of 3rd ventricle
Medially: Cavity of 3rd ventricle
Laterally: Internal capsule.

Note: *Hypothalamic sulcus* extends from the interventricular foramen to the cerebral aqueduct. This sulcus separates hypothalamus from thalamus.

Flowchart 10.4: Hypothalamus


Hypothalamus
Part of diencephalon
Functions
Regulates
- Autonomic nervous system
- Body temperature
- Food and water intake
- Pituitary gland
- Emotion, sexual behaviour, and reproduction
Boundaries
Anteriorly: Lamina terminalis
Posteriorly: Subthalamus
Superiorly: Thalamus
Inferiorly: Floor of 3rd ventricle
Medially: Cavity of 3rd ventricle
Laterally: Internal capsule
Parts
Preoptic part
Supraoptic region
Tuberal region
Mammillary region


Fornix
Corpus callosum
Interventricular foramen
Anterior commissure
Lamina terminalis
Optic nerve
Optic chiasma
Hypophysis cerebri
Mammillary body
Posterior perforated substance
Interthalamic adhesion
Hypothalamic sulcus
Hypothalamus forming lateral wall of third ventricle
Tegmentum of midbrain
(a)
Optic tract
Crus cerebri
Pons (superior border)
Optic chiasma
Infundibulum
Mammillary body
Posterior perforated substance
(b)

Figs 10.9a and b: (a) Hypothalamus as seen in sagittal section and (b) hypothalamus viewed at the base of brain

Parts of the Hypothalamus

The hypothalamus is divided into four regions or parts:

1. *Preoptic part*: It lies anteriorly between optic chiasma and anterior commissure. It consists of preoptic nucleus.
2. *Supraoptic region*: It lies above the optic chiasma. It consists of supraoptic, anterior, and paraventricular nuclei.
3. *Tuberal region*: It includes tuber cinereum, arcuate nucleus, ventromedial and dorsomedial nuclei.
4. *Mammillary region*: It includes mammillary body and posterior nucleus.

Note:

- Anterior column of fornix, mammillothalamic tract, and fasciculus retroflexes traverse the hypothalamus.
- *Tuber cinereum* is an elevation produced by grey matter. It lies between optic chiasma and mammillary bodies.
- *Infundibulum* is a pituitary stalk which passes inferiorly from the centre of tuber cinereum.
- *Median eminence* is an elevated part of tuber cinereum at the attachment of infundibulum.
- *Mammillary bodies* are paired, small spherical masses. They lie in between tuber cinereum and posterior perforated substance of interpeduncular fossa. They are masses of gray matter covered by white fibres. They form a part of limbic system.

Hypothalamic Nuclei and Connections

The hypothalamic nuclei are named according to their location as preoptic, supraoptic, paraventricular, anterior, arcuate, ventromedial, dorsomedial, posterior, mammillary, and lateral nuclei (Fig. 10.10, Flowchart 10.5). Their functions are listed in Table 10.3.

Afferent Fibres for Hypothalamus

1. *Medial forebrain bundle* connects medial olfactory area (that is olfactory bulb and anterior perforated substance) to the preoptic and lateral nuclei.
2. *Fornix* connects the hippocampus to mammillary body.
3. *Stria terminalis* connects the amygdaloid nucleus to preoptic and anterior thalamic nuclei.
4. *Ansa lenticularis* (pallido-hypothalamic fibres) connects the lentiform nucleus of basal ganglia to ventromedial nucleus of hypothalamus.
5. *Thalamohypothalamic fibres* from thalamus.
6. Corticohypothalamic fibres.
7. *Mammillary peduncle* connects the spinal cord and brainstem to the lateral hypothalamus nuclei.

TABLE 10.3: Hypothalamic nucleus and their functions

Nucleus	***Function***
Preoptic	Controls the release of gonadotropic hormones from the adenohypophysis
Supraoptic	Produces ADH and oxytocin
Paraventricular	Produces hypothalamic releasing and inhibiting hormones
Anterior	Regulates parasympathetic activity Regulates body temperature
Arcuate or infundibular	Produces hypothalamic releasing and inhibiting hormones
Ventromedial	It is a satiety and hunger centre
Dorsomedial	It causes obesity
Posterior	Regulates sympathetic activity Regulates body temperature by conservation of heat and production of heat (thermostat centre)
Mammillary	Emotional expression (part of limbic system)
Lateral	It is a feeding centre
Suprachiasmatic	Regulates circadian rhythm (acts as master clock)

ADH: Antidiuretic hormone.

Efferent Fibres of Hypothalamus

1. *Mammillothalamic* tract connects mammillary body to anterior nucleus of hypothalamus.
2. *Mammillotegmental* tract connects mammillary body to the reticular formation of brainstem.
3. Descending fibres to spinal cord and brainstem.
4. *Supraoptico-hypophyseal* and *tubero-infundibular fibres* are axons of supraoptic and paraventricular nuclei

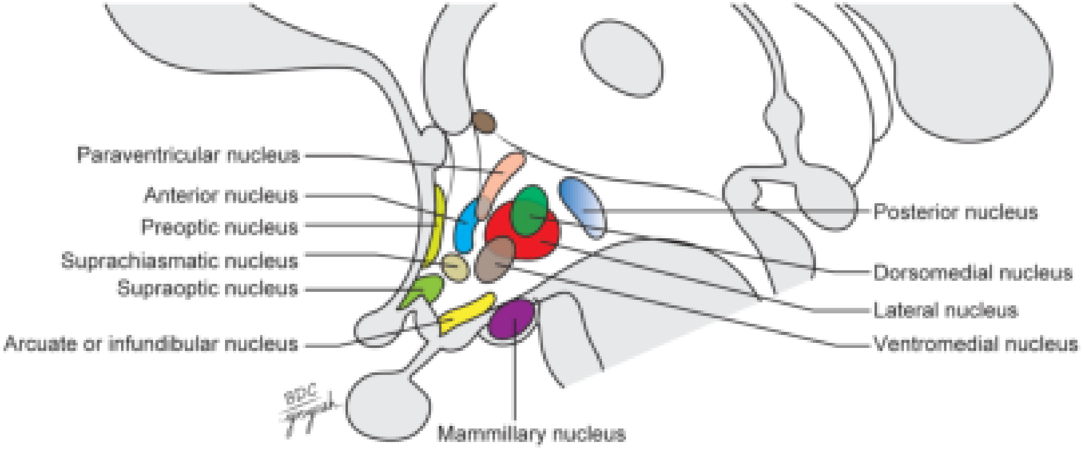
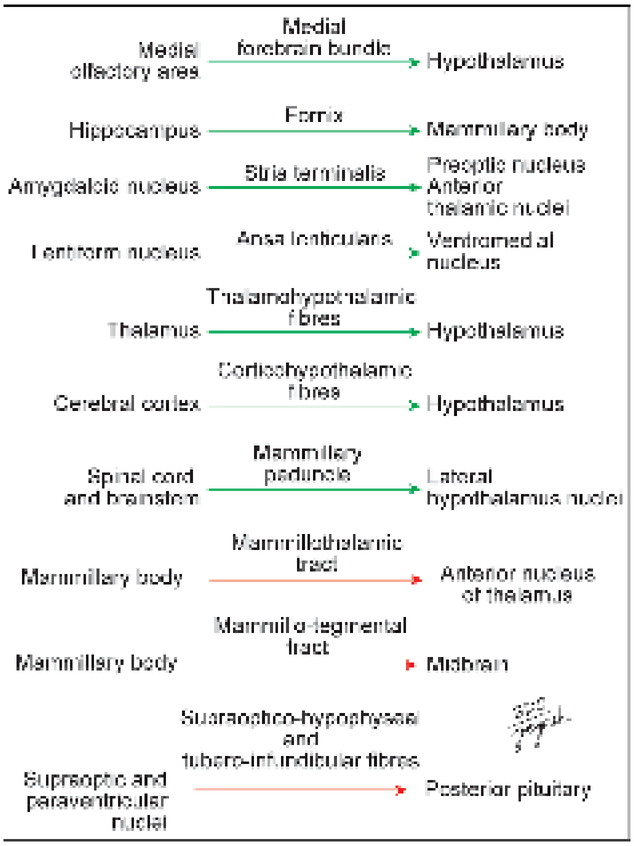


Fig. 10.10: Nuclei of hypothalamus

Flowchart 10.5: Major connections of hypothalamus


Medial olfactory area
Medial forebrain bundle
Hypothalamus
Hippocampus
Fornix
Mammillary body
Amygdaloid nucleus
Stria terminalis
Preoptic nucleus
Anterior thalamic nuclei
Lentiform nucleus
Ansa lenticularis
Ventromedial nucleus
Thalamus
Thalamohypothalamic fibres
Hypothalamus
Cerebral cortex
Corticohypothalamic fibres
Hypothalamus
Spinal cord and brainstem
Mammillary peduncle
Lateral hypothalamus nuclei
Mammillary body
Mammillothalamic tract
Anterior nucleus of thalamus
Mammillary body
Mammillo-tegmental tract
Midbrain
Supraoptico-hypophyseal and tubero-infundibular fibres
Supraoptic and paraventricular nuclei
Posterior pituitary

of hypothalamus that pass through infundibulum to the posterior pituitary. The hormones stored in their axon terminals produce *Herring bodies*. They secrete vasopressin and oxytocin hormones.

Functions of Hypothalamus

The hypothalamus is a complex neuroglandular mechanism concerned with regulation of visceral and vasomotor activities of the body. Its functions are as follows:

1. Controls autonomic nervous system
2. Regulates body temperature
3. Regulates food and water intake
4. Regulates endocrine function of anterior and posterior pituitary gland
5. Regulates emotion, sexual behavior, and reproduction
6. Maintains circadian rhythm (biological clock).

For details of hypothalamo-hypophyseal portal circulation, *see* Volume 3, Chapter 12.

CLINICAL NEUROANATOMY

Hypothalamic disorders: The vascular lesions or any other disorder of hypothalamus result on the following conditions:

1. Diabetes insipidus due to lack of ADH secretion
2. Polydipsia and polyuria
3. Obesity due to overeating (polyphagia)
4. Somnolence (drowsiness or sleepiness)
5. Loss of temperature control (poikilothermia), may be hyperthermia
6. Loss of sexual desires
7. Dehydration due to lack of water intake
8. Aggressive behaviour, rage, or extreme passivity.

These symptoms may not be completely observed. There may be aphagia instead of polyphagia.

SUBTHALAMUS

The subthalamus lies between the midbrain and thalamus, medial to internal capsule and the globus pallidus (Fig. 10.11). It consists of the following:

Grey Matter

1. The cranial ends of the red nucleus and substantia nigra extend into it.
2. Subthalamic nucleus
3. Zona incerta.

White Matter

1. Cranial ends of lemnisci—lateral to the red nucleus
2. Dentatothalamic tract along with the rubrothalamic fibres
3. Ansa lenticularis (ventral)
4. Fasciculus lenticularis (dorsal)
5. Subthalamic fasciculus (intermediate fibres).

The ***subthalamic nucleus*** is a lens-shaped nucleus lying on the medial aspect of internal capsule just above the substantia nigra. It is one of the extrapyramidal nuclei that modifies motor activity.

The ***zona incerta*** is a thin lamina of grey matter situated between the thalamus and the subthalamic nucleus. Laterally, it is continuous with the reticular nucleus of the thalamus. Its activity influences drinking of water.

The ***fasciculus lenticularis*** (*lenticular fasciculus*) consists of fibres of globus pallidus that pass through the internal capsule to the subthalamus nucleus.

The ***ansa lenticularis*** is an inferior bundle of fibres from globus pallidus to thalamus and other subthalamic nuclei.

The ***thalamic fasciculus*** (*Field H1 of Forel*) is a group of fibres extending from prerubral field to the thalamus. It also has some fibres from fasciculus.

CLINICAL NEUROANATOMY

Discrete lesions of the subthalamic nucleus result in ***hemiballismus*** characterised by involuntary choreiform movements on the opposite side of the body. The condition is abolished by ablation of the globus pallidus or of its efferent tracts, the anterior ventral nucleus of the thalamus, area 4 of the cerebral cortex, or of the corticospinal tract. From these facts, it appears that the subthalamic nucleus has an inhibitory control on the globus pallidus and on the cerebral cortex.

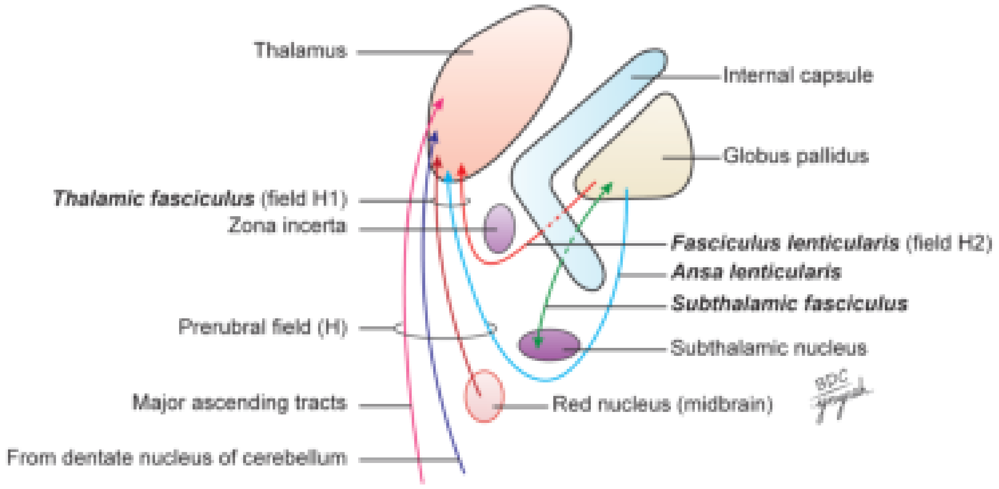


Fig. 10.11: Important fibre bundle running through subthalamic region

***Competency*:**
AN63.1 Describe and demonstrate parts, boundaries and features of IIIrd ventricle.

THIRD VENTRICLE

The third ventricle is a median cleft between the two thalami. Developmentally, it represents the cavity of the diencephalon, except for the area in front of the interventricular foramen which is derived from the median part of the telencephalon. The cavity is lined by ependyma (Fig. 10.12 and Flowchart 10.6).

Extent

It extends from lamina terminalis anteriorly to the cerebral aqueduct posteriorly.

Contents

1. Cerebrospinal fluid
2. Interthalamic adhesion (covered by ependyma lining).

Communications

Anterosuperiorly, on each side, it communicates with the lateral ventricle through the ***interventricular foramen*** (foramen of Monro). This foramen is bounded anteriorly by the column of the fornix, and posteriorly by the tubercle of the thalamus.

Posteroinferiorly, in the median plane, it communicates with the fourth ventricle through the cerebral aqueduct.

Boundaries

Anterior Wall

1. Lamina terminalis
2. Anterior commissure
3. Anterior columns of fornix. The two columns of the fornix diverge, pass downwards and backwards, and sink into the lateral wall of the third ventricle to reach the mammillary body.

Posterior Wall

1. Pineal body
2. Posterior commissure (in the lower lamina of the pineal stalk)
3. Cerebral aqueduct.

Roof

It is formed by body of fornix and the ependyma lining the under surface of the tela choroidea of the 3rd ventricle. The choroid plexus of the third ventricle projects downwards from the roof.

At the junction of the roof with the anterior and lateral walls, there is the interventricular foramen.

Floor

It is formed by hypothalamic structures:

1. Optic chiasma
2. Infundibulum (pituitary stalk) and tuber cinereum
3. Mammillary bodies
4. Posterior perforated substance
5. Tegmentum of the midbrain.

At the junction of the floor with the anterior wall, there is the optic recess.

Lateral Wall

It is formed by the following:

1. Medial surface of thalamus (in its posterosuperior part)
2. Hypothalamus (in its anteroinferior part)
3. The hypothalamic sulcus which separates the thalamus from the hypothalamus. The sulcus extends from the interventricular foramen to the cerebral aqueduct.

Note:

a. The interthalamic adhesion connects the medial surfaces of the two thalami and crosses the ventricular cavity.
b. The habenular stria lies at the junction of the roof and the lateral wall. The two striae join posteriorly at the habenular commissure.
c. The columns of the fornix, as already indicated, run downwards and backwards to reach the mammillary bodies. The columns lie beneath the lateral wall of the ventricle.

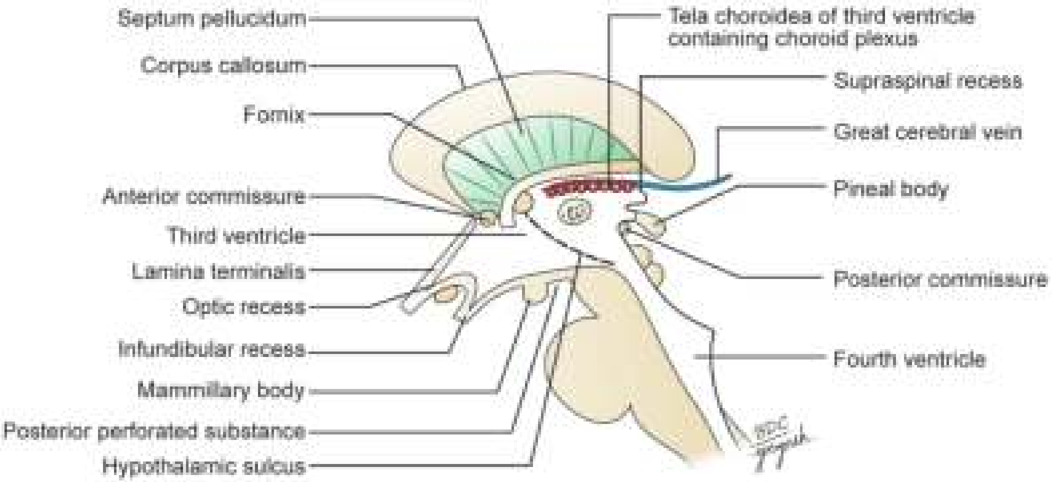
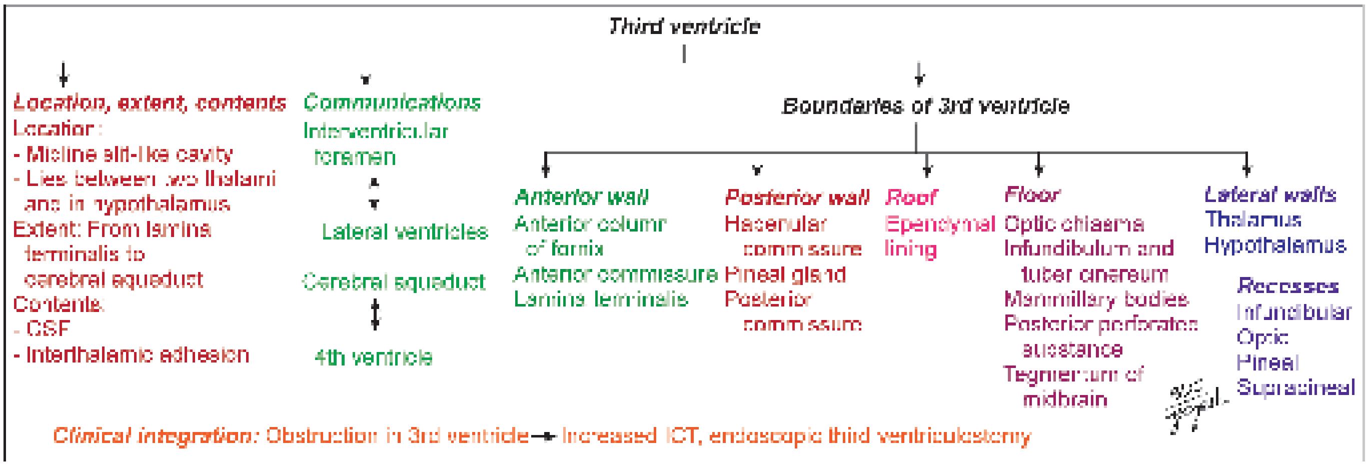

Septum pellucidum
Corpus callosum
Fornix
Anterior commissure
Third ventricle
Lamina terminalis
Optic recess
Infundibular recess
Mammillary body
Posterior perforated substance
Hypothalamic sulcus
Tela choroidea of third ventricle containing choroid plexus
Supraspinal recess
Great cerebral vein
Pineal body
Posterior commissure
Fourth ventricle

Fig. 10.12: Boundaries of third ventricle

Flowchart 10.6: Third ventricle


Third ventricle
Location, extent, contents
Location:
- Midline slit-like cavity
- Lies between two thalami and in hypothalamus
Extent: From lamina terminalis to cerebral aqueduct
Contents
- CSF
- Interthalamic adhesion
Communications
Interventricular foramen
Lateral ventricles
Cerebral aqueduct
4th ventricle
Boundaries of 3rd ventricle
Anterior wall
Anterior column of fornix
Anterior commissure
Lamina terminalis
Posterior wall
Habenular commissure
Pineal gland
Posterior commissure
Roof
Ependymal lining
Floor
Optic chiasma
Infundibulum and tuber cinereum
Mammillary bodies
Posterior perforated substance
Tegmentum of midbrain
Lateral walls
Thalamus
Hypothalamus
Recesses
Infundibular
Optic
Pineal
Suprapineal
Clinical integration: Obstruction in 3rd ventricle → Increased ICT, endoscopic third ventriculostomy

Recesses

Recesses are extensions of the cavity. They are as follows:

1. *Infundibular recess* – extends downward into the infundibulum of pituitary gland.
2. *Optic or chiasmatic recess* – extends anteriorly into the optic chiasma
3. *Pineal recess* – extends posteriorly into the stalk of the pineal gland
4. *Suprapineal recess* – extends posteriorly above the stalk of pineal gland and below the tela choroidea.

Note:

- ***Tela choroidea*** is the region where pia mater and ependyma adhere with each other without intervening neuronal tissue. (*Tela* = Woven, in Latin). It contains a thin layer of connective tissue and numerous blood vessels. It forms choroid plexuses in ventricles that produce cerebrospinal fluid (CSF).
- ***Choroid plexuses of 3rd ventricle*** hang downwards from tela choroidea of 3rd ventricle as two longitudinal finger-like projections that run anteroposteriorly. They are continuous with the choroid plexus of lateral ventricle.

CLINICAL NEUROANATOMY

- ***Obstruction in 3rd ventricle:*** The third ventricle is a narrow space which is easily obstructed by local brain tumours or by developmental defects. The obstruction leads to raised intracranial pressure in adults and hydrocephalus in infants.
- Tumours in the lower part of the third ventricle give rise to hypothalamic symptoms, like diabetes insipidus, obesity, sexual disturbance, disturbance of sleep, hyperglycaemia and glycosuria.
- ***Endoscopic third ventriculostomy:*** It is an endoscopic procedure that may be performed to release excess CSF in hydrocephalus cases. It is performed through the floor of the 3rd ventricle, in between two mammillary bodies.

DISSECTION

Identify the extent of the third ventricle from the lamina terminalis anteriorly to the upper end of the aqueduct and root of pineal body posteriorly. Examine its anterior wall, posterior wall, roof, floor and lateral walls.

Facts to Remember

- Thalamus is the inner chamber receiving and coordinating motor, sensory, visceral, visual, auditory and emotional impulses.
- Third ventricle is a slit-like ventricle in between the two thalami.
- Aqueduct is the narrow duct connecting 3rd ventricle above with the fourth ventricle below.
- All the sensory pathway relay in thalamus except olfactory pathway.
- Lateral geniculate body is a relay centre for the visual pathway, whereas the medial geniculate bosy is for the auditory pathway.
- Pineal gland is called third eye and it secretes melatonin.
- Hypothalamus is the main centre of autonomic nervous system.

BDC's Anatomy *e*-book

1. Location of thalamic nuclei
2. Stria medullaris thalami
3. Further reading
4. Viva voce questions

Chapter 11

Cerebrum, Basal Nuclei and White Matter

CEREBRUM

The cerebrum (Latin *brain*) is the ***largest part of the brain***. It is also known as ***pallium***. It occupies anterior, middle cranial fossae and the supratentorial part of the posterior cranial fossa (Figs 11.1a and b and 11.2).

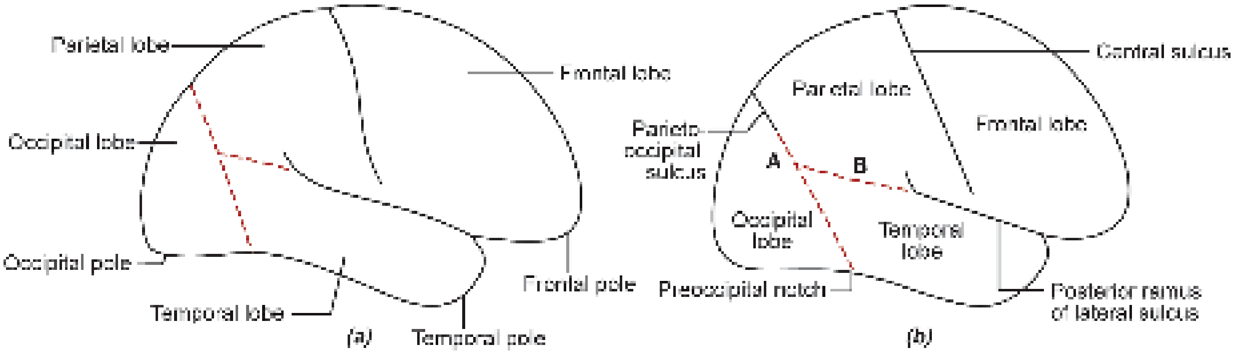
Components of Cerebral Hemisphere

It is made up of:

1. Outer grey matter
2. Inner white matter
3. Basal ganglia or nuclei – some neuronal masses within the white matter
4. Diencephalon
5. A cavity called lateral ventricle.

The cerebrum is made of two cerebral hemispheres which are incompletely separated from each other by the median ***longitudinal fissure***.

The two hemispheres are connected to each other across the median plane by the ***corpus callosum***. Each hemisphere contains a cavity, called the ***lateral ventricle***. The surface area of cerebrum is 2000 cm^2.


Parietal lobe
Frontal lobe
Occipital lobe
Occipital pole
Frontal pole
Temporal lobe
(a)
Temporal pole
Central sulcus
Parietal lobe
Parieto-occipital sulcus
Frontal lobe
A
B
Occipital lobe
Temporal lobe
Preoccipital notch
Posterior ramus of lateral sulcus
(b)

Figs 11.1a and b: Superolateral surface of cerebral hemisphere

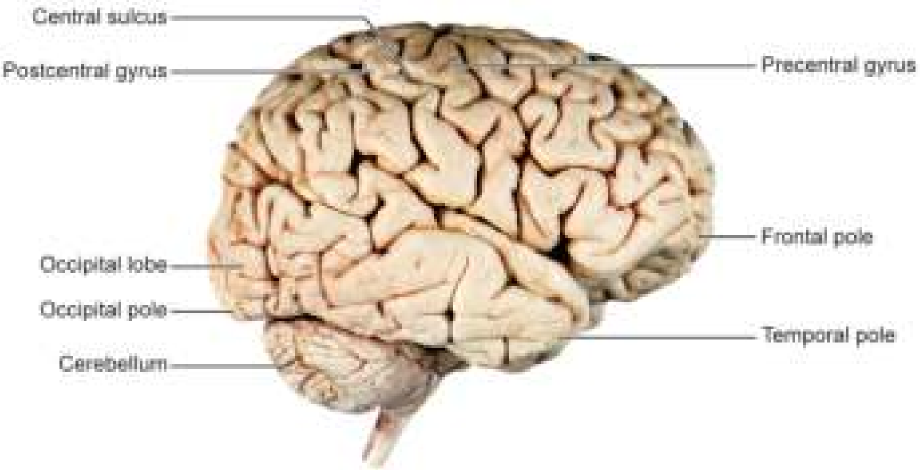

Central sulcus
Postcentral gyrus
Precentral gyrus
Frontal pole
Occipital lobe
Occipital pole
Temporal pole
Cerebellum

Fig. 11.2: Superolateral surface of cerebral hemisphere

Cerebral Sulci and Gyri

Cerebral cortex is folded into ***gyri*** (Greek *circle*) which are separated from each other by ***sulci*** (Figs 11.3 to 11.5).

Note: Sulci and gyri increase the surface area of the cortex. In human brain, the total area of the cortex is estimated to be more than 2000 cm^2, and approximately 2/3rd of this area is hidden from the surface within the sulci.

The pattern of folding of the cortex is not entirely haphazard. It is largely determined by the differential growth of specific functional areas of the cortex, because many of the sulci bear a definite topographical relation to these areas. The formation of sulci in the intrauterine life begins from 5th–6th month and ends almost at the end of 9th month.

DISSECTION

Keep the cerebrum in a position so that the longitudinal fissure faces superiorly. Identify the convex strong band of white matter, the corpus callosum, binding parts of the medial surfaces of the two cerebral hemispheres. Define splenium as the thick rounded part of corpus callosum.

Divide the corpus callosum in the median plane starting from the splenium towards the trunk, genu and rostrum. Inferior to the trunk of corpus callosum extend the incision into the tela choroidea of the lateral and third ventricles, and the interthalamic adhesion connecting the medial surfaces of two thalami.

Identify the thin septum pellucidum connecting the inferior surfaces of corpus callosum to a curved band of white matter—anterior column of the fornix. Look for the anterior commissure just at the anterior end of the anterior column of fornix.

Turn the brain upside down and identify optic chiasma. Divide the optic chiasma, anterior communicating artery, infundibulum and a thin groove between the adjacent mammillary bodies, posterior cerebral artery close to its origin. Carry the line of division around the midbrain to

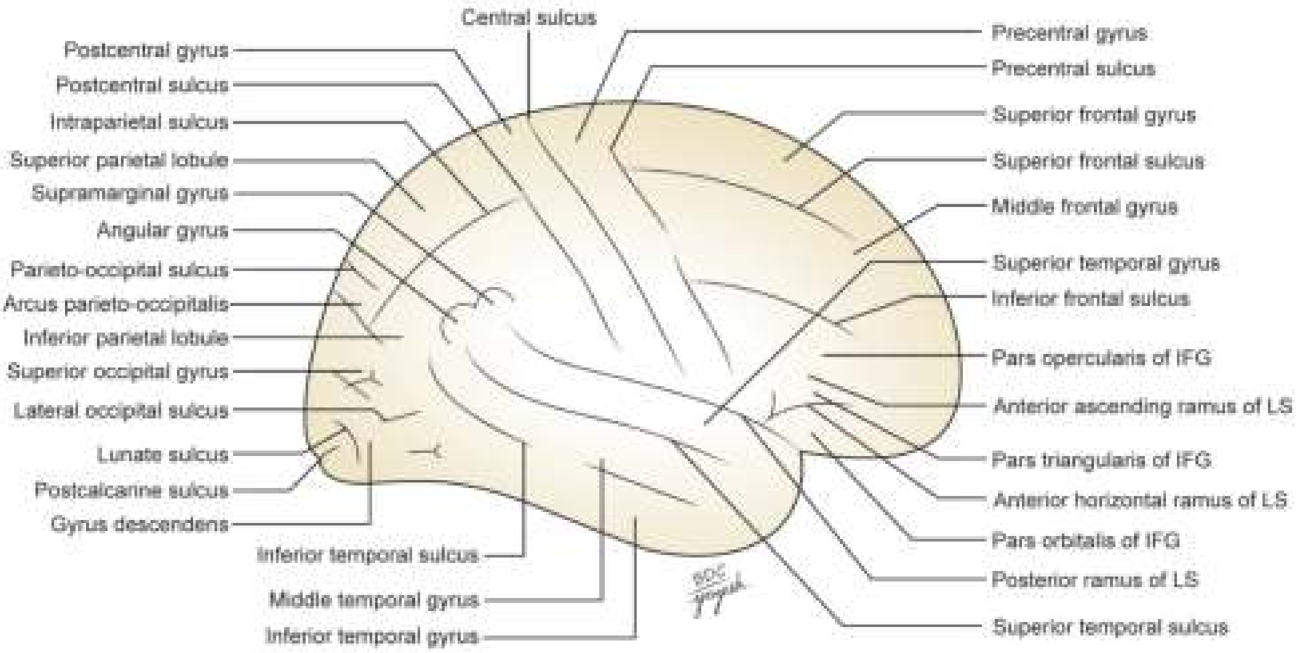

Central sulcus
Postcentral gyrus
Postcentral sulcus
Intraparietal sulcus
Superior parietal lobule
Supramarginal gyrus
Angular gyrus
Parieto-occipital sulcus
Arcus parieto-occipitalis
Inferior parietal lobule
Superior occipital gyrus
Lateral occipital sulcus
Lunate sulcus
Postcalcarine sulcus
Gyrus descendens
Inferior temporal sulcus
Middle temporal gyrus
Inferior temporal gyrus
Precentral gyrus
Precentral sulcus
Superior frontal gyrus
Superior frontal sulcus
Middle frontal gyrus
Superior temporal gyrus
Inferior frontal sulcus
Pars opercularis of IFG
Anterior ascending ramus of LS
Pars triangularis of IFG
Anterior horizontal ramus of LS
Pars orbitalis of IFG
Posterior ramus of LS
Superior temporal sulcus

Fig. 11.3: Sulci and gyri on superolateral surface of cerebral hemisphere (IFG: Inferior frontal gyrus; LS: Lateral sulcus)

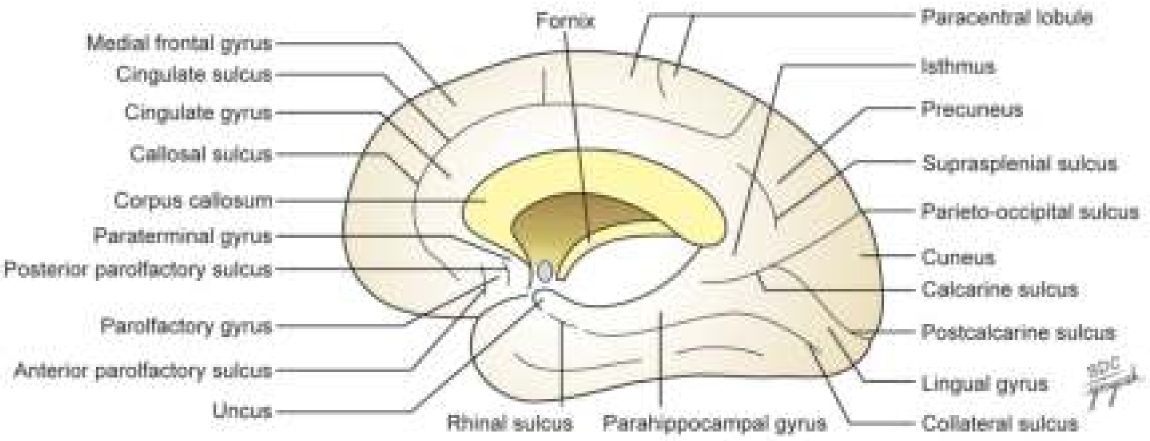

Fornix
Medial frontal gyrus
Cingulate sulcus
Cingulate gyrus
Callosal sulcus
Corpus callosum
Paraterminal gyrus
Posterior parolfactory sulcus
Parolfactory gyrus
Anterior parolfactory sulcus
Uncus
Rhinal sulcus
Parahippocampal gyrus
Paracentral lobule
Isthmus
Precuneus
Suprasplenial sulcus
Parieto-occipital sulcus
Cuneus
Calcarine sulcus
Postcalcarine sulcus
Lingual gyrus
Collateral sulcus

Fig. 11.4: Sulci and gyri on the medial surface of cerebral hemisphere

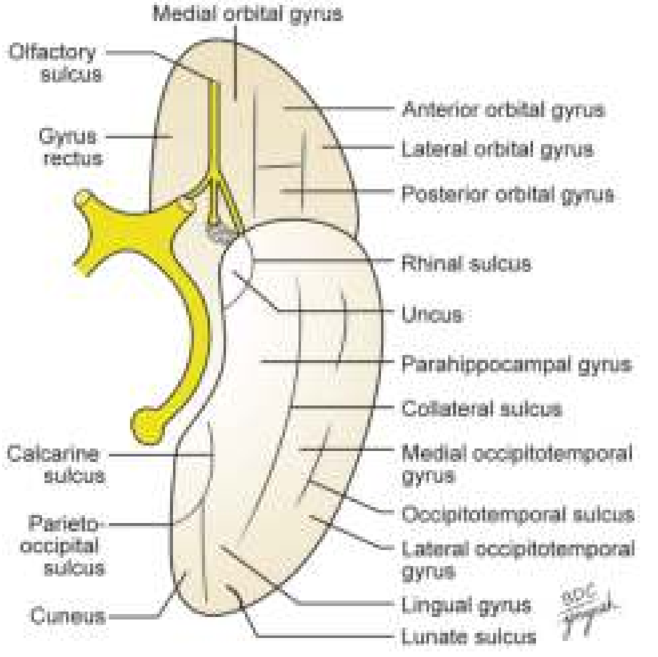

Medial orbital gyrus
Olfactory sulcus
Gyrus rectus
Anterior orbital gyrus
Lateral orbital gyrus
Posterior orbital gyrus
Rhinal sulcus
Uncus
Parahippocampal gyrus
Collateral sulcus
Calcarine sulcus
Medial occipitotemporal gyrus
Occipitotemporal sulcus
Parieto-occipital sulcus
Lateral occipitotemporal gyrus
Cuneus
Lingual gyrus
Lunate sulcus

Fig. 11.5: Gyri and sulci on the inferior aspect of cerebral hemisphere

join the two ends of the median cut. Separate the right and the left cerebral hemispheres.

In the two hemispheres, identify the three surfaces, four borders, and three poles. Identify the central sulcus, posterior ramus of lateral sulcus, parieto-occipital sulcus and preoccipital notch. Join parieto-occipital sulcus to preoccipital notch. Extend the line of posterior ramus of lateral sulcus till the previous line. Now demarcate the four lobes of the superolateral surface of each cerebral hemisphere.

Strip the meninges from the surfaces. Identify the vessels on the surfaces of hemisphere. Demarcate the main sulci and gyri on the superolateral surface, medial surface and inferior surface of hemisphere.

Make thin slice through the part of the calcarine sulcus, posterior to its junction with the parieto-occipital sulcus. Identify the stria running through it. On cutting series of thin slices try to trace the extent of visual stria.

Competency:

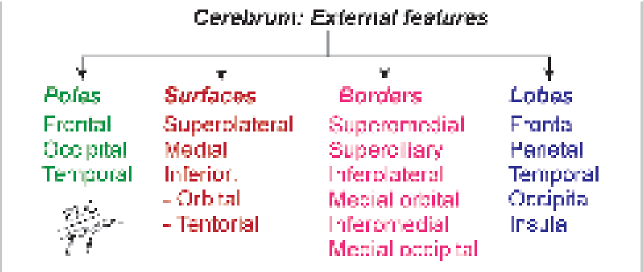
AN62.2 Describe and demonstrate surfaces, sulci, gyri, poles, and functional areas of cerebral hemisphere. Also describe the effects of damage to various functional areas of cerebral cortex.

EXTERNAL FEATURES OF CEREBRAL HEMISPHERE

Each cerebral hemisphere has the following features (Figs 11.1 to 11.5, Flowchart 11.1):

- Poles: Frontal, occipital, and temporal
- Surfaces: Superolateral, medial, inferior (orbital and tentorial)
- Borders: Superomedial, superciliary, inferolateral, medial orbital, inferomedial, medial occipital.
- Lobes: Frontal, parietal, temporal, occipital, insula.

Flowchart 11.1: Cerebrum: External features


Cerebrum: External features
Poles
Frontal
Occipital
Temporal
Surfaces
Superolateral
Medial
Inferior.
- Orbital
- Tentorial
Borders
Superomedial
Superciliary
Inferolateral
Medial orbital
Inferomedial
Medial occipital
Lobes
Frontal
Parietal
Temporal
Occipital
Insula

Poles of Cerebral Hemisphere

1. *Frontal pole,* at the anterior end.
2. *Occipital pole,* at the posterior end.
3. *Temporal pole,* at the anterior end of the temporal lobe.

Surfaces of Cerebral Hemisphere

1. ***Superolateral surface*** is convex and is related to the cranial vault.
2. ***Medial surface*** is flat and vertical. It is separated from the corresponding surface of the opposite hemisphere by the falx cerebri and the longitudinal fissure.
3. ***Inferior surface*** is divided into an anterior part—the *orbital surface,* and a posterior part—the *tentorial surface.* The two parts are separated by a deep cleft called the stem of the lateral sulcus.

Borders of Cerebral Hemisphere

1. ***Superomedial border*** separates the superolateral surface from the medial surface.
2. ***Inferolateral border*** separates the superolateral surface from the inferior surface. The anterior part of this border is called the ***superciliary border***. There is a depression on the inferolateral border situated about 5 cm in front of the occipital pole, it is called the ***preoccipital notch***.
3. ***Medial orbital border*** separates the medial surface from the orbital surface.
4. ***Medial occipital border*** separates the medial surface from the tentorial surface.
5. The ***inferomedial (hippocampal) border*** surrounds the cerebral peduncle. It is formed by the medial aspect of the uncus and parahippocampal gyrus.

Lobes of Cerebral Hemisphere

Each cerebral hemisphere is divided into four lobes—frontal, parietal, occipital and temporal. The sulci separating the lobes on this surface are as follows (Figs 11.1 to 11.5):

1. ***Central sulcus*** begins at the superomedial border of the hemisphere a little behind the midpoint between the frontal and occipital poles. It runs on the superolateral surface obliquely downwards and forwards and ends a little above the posterior ramus of the lateral sulcus.
2. It is seen that the ***lateral sulcus*** separates the orbital and tentorial parts of the inferior surface. Laterally, this sulcus reaches the superolateral surface where

it divides into anterior, ascending and posterior branches. The largest of these, the *posterior ramus of the lateral sulcus* passes backwards and slightly upwards over the superolateral surface.

3. ***Parieto-occipital sulcus*** is a sulcus of the medial surface. Its upper end cuts off the superomedial border about 5 cm in front of the occipital pole.
4. ***Preoccipital notch*** is an indentation on the inferolateral border, about 5 cm in front of the occipital pole.

The division is completed by drawing an imaginary vertical line joining the parieto-occipital sulcus to the preoccipital notch; and another horizontal line continuing backwards from the posterior ramus of the lateral sulcus to meet the first line as follows:

1. ***Frontal lobe*** lies anterior to central sulcus and above the posterior ramus of lateral sulcus.
2. ***Parietal lobe*** lies behind the central sulcus and in front of an imaginary vertical line joining the parieto-occipital sulcus and preoccipital notch. It lies above the horizontal line drawn from the horizontal part of posterior ramus of lateral sulcus.
3. ***Temporal lobe*** lies below the posterior ramus of lateral sulcus and horizontal line extending backward from horizontal part of this sulcus. It lies anterior to imaginary vertical line joining the parieto-occipital sulcus and preoccipital notch.
4. ***Occipital lobe*** lies behind the vertical line joining the parieto-occipital sulcus and preoccipital notch.

Insula (Island of Reil or Central Lobe)

Insula lies deep in the floor of lateral fissure surrounded by a circular sulcus and overlapped by adjacent cortical areas—the ***opercula*** (Plate 11.1 and Flowchart 11.2):

1. Insula comprises ***frontal operculum*** between anterior and ascending rami of lateral sulcus.
2. ***Parietal operculum*** lies between ascending and posterior rami of lateral sulcus.
3. ***Temporal opercula*** below posterior ramus of lateral sulcus formed by superior temporal gyri.

Insula is a pyramidal area, apex near anterior perforated substance.

The insula is divided into two regions: Anterior and posterior by a central sulcus. The anterior region presents 3 or 4 short gyri called *gyri brevia* and the posterior region presents 1 or 2 long gyri called *gyri longa*.

Functions:

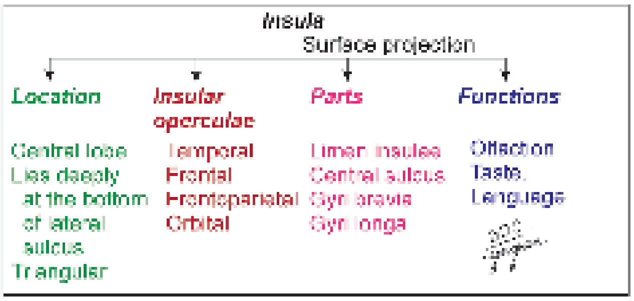
1. Role of anterior insular cortex is in olfaction and taste.
2. Role of posterior insular cortex is in language function.

Sulci and Gyri on Superolateral Surface

(Fig. 11.3, Table 11.1)

1. ***Central sulcus*** *(of Rolando)* (Latin *furrow*): It begins at the superomedial border of the hemisphere about 1 cm behind the midpoint between the frontal and occipital poles. It runs on the superolateral surface obliquely downwards and forwards and ends a little above the posterior ramus of the lateral sulcus. The upper end of the sulcus extends for a short distance onto the medial surface.

Flowchart 11.2: Insula



2. ***Lateral sulcus*** begins on the inferior surface. On reaching the lateral surface, it divides into three rami.
   - ***Anterior ramus*** (2.5 cm) passes forward into the inferior frontal gyrus.
   - ***Anterior ascending ramus*** (2.5 cm) runs upward in the inferior frontal gyrus.
   - ***Posterior ramus*** (7.5 cm) runs posteriorly and upward up to the inferior parietal lobule. Its posterior end upturns sharply.
3. ***In the frontal lobe*: **The frontal lobe is further divided by the following sulci:
   a. ***Precentral sulcus*** runs parallel to the central sulcus, a little in front of it. The ***precentral gyrus*** lies between the two sulci.
   b. The area in front of the precentral sulcus is divided into ***superior, middle and inferior frontal gyri*** by the ***superior and inferior frontal sulci***.
   c. The anterior horizontal and anterior ascending rami of the lateral sulcus subdivide the inferior frontal gyrus into three parts: *Pars orbitalis, pars triangularis,* and *pars opercularis.*
4. ***In the parietal lobe*: **The parietal lobe is further subdivided by the following sulci:
   a. ***Postcentral sulcus*** runs parallel to the central sulcus, a little behind it. The ***postcentral gyrus*** lies between the two sulci.
   b. The area behind the postcentral gyrus is divided into the ***superior* and *inferior parietal lobules*** by the ***intraparietal sulcus***.
   c. The inferior parietal lobule is invaded by the upturned ends of the posterior ramus of the lateral sulcus, and of the superior and inferior temporal sulci. They divide the inferior parietal lobule into anterior, middle and posterior parts:
      - The anterior part that surrounds the posterior ramus of lateral sulcus is called ***supramarginal gyrus***.
      - The middle part surrounding the superior temporal sulcus is the angular gyrus.
      - The posterior and lower part surrounding the inferior temporal sulcus is the arcus temporo-occipitalis.
5. ***In the temporal lobe:*** The ***superior and inferior temporal sulci*** divide the temporal lobe into ***superior, middle and inferior temporal gyri***.

Plate 11.1: Insula (island of Reil) (exposed by pulling the opercula)

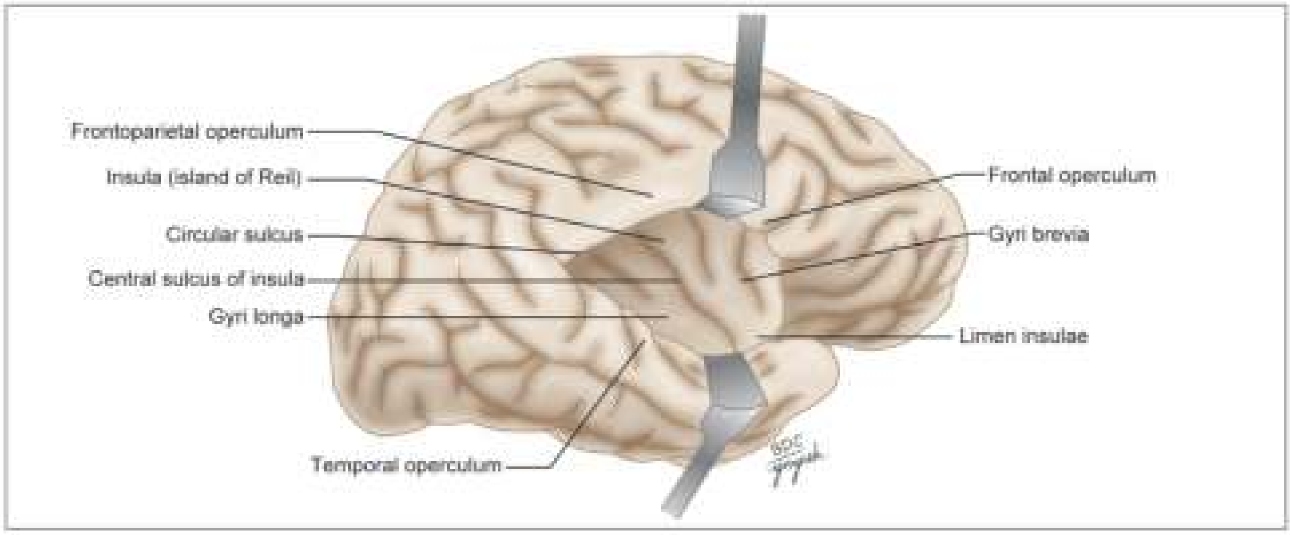


TABLE 11.1: Sulci and gyri of the cerebrum

Surface/lobe	*Sulci*	*Gyri*
I. Superolateral surface		
Frontal lobe	1. Precentral 2. Superior frontal 3. Inferior frontal	a. Precentral b. Superior frontal c. Middle frontal d. Inferior frontal which also contains anterior horizontal and anterior ascending rami of the lateral sulcus, and the pars orbitalis, pars triangularis and pars opercularis
Parietal lobe	1. Postcentral 2. Intraparietal	a. Postcentral b. Superior parietal lobule c. Inferior parietal lobule, which is divided into 3 parts: i. Anterior – supramarginal ii. Middle – angular iii. Posterior – over the upturned end of inferior temporal sulcus
Temporal lobe	1. Superior temporal 2. Inferior temporal	a. Superior temporal b. Middle temporal c. Inferior temporal
Occipital lobe	1. Lateral occipital 2. Lunate 3. Superior and inferior polar 4. Calcarine 5. Transverse occipital	a. Arcus parieto-occipitalis b. Superior occipital c. Inferior occipital d. Gyrus descendens
II. Medial surface	1. Anterior parolfactory 2. Posterior parolfactory 3. Cingulate 4. Callosal 5. Suprasplenial or subparietal 6. Parieto-occipital 7. Calcarine	a. Paraterminal b. Paraolfactory (subcallosal area) c. Medial frontal d. Paracentral lobule e. Cingulate f. Cuneus g. Precuneus
III. Inferior surface	1. Olfactory 2. H-shaped orbital sulci 3. Collateral 4. Rhinal 5. Occipitotemporal	a. Gyrus rectus b. Anterior orbital c. Posterior orbital d. Medial orbital e. Lateral orbital f. Uncus g. Parahippocampal h. Medial occipitotemporal i. Lateral occipitotemporal j. Lingual

6. ***In the occipital lobe:*** The occipital lobe is further subdivided by the following sulci:
    a. ***Lateral occipital sulcus*** divides this lobe into the ***superior and inferior occipital gyri***.
    b. ***Lunate sulcus*** separates these gyri from the occipital pole.
    c. The area around the ***parieto-occipital sulcus*** is the ***arcus parieto-occipitalis***. It is separated from the superior occipital gyrus by the ***transverse occipital sulcus***.
    d. ***Calcarine sulcus*** begins near the occipital pole and runs forward to a point below the splenium of corpus callosum, where it is joined at an acute angle by medial part of the parieto-occipital sulcus.

Note: The ***arcus parieto-occipitalis*** lies in both parietal and occipital lobes.

Sulci and Gyri on Medial Surface (Fig. 11.4)

1. ***Corpus callosum*:** The central part of the medial aspect of the hemisphere is occupied by the ***corpus callosum***. The corpus callosum is divisible into the *genu* (anterior end), the *body*, and the *splenium* (posterior end). It is made up of nerve fibres connecting the two cerebral hemispheres. Below the corpus callosum, there are the *septum pellucidum*, the *fornix* and the *thalamus*.
2. *Sulci on the medial surface*
    a. ***Cingulate sulcus*** starts in front of the genu of corpus callosum and runs backwards parallel to the upper margin of the corpus callosum.
    b. ***Callosal sulcus*** separates the cingulate gyrus from the corpus callosum.
    c. ***Suprasplenial sulcus*** lies above and behind the splenium.
    d. ***Calcarine sulcus*** begins a little below the splenium and runs towards the occipital pole. It extends for a short distance on the superolateral surface.
    e. ***Parieto-occipital sulcus*** begins at the midpoint of the calcarine sulcus. It runs upward and slightly backward to intersect the superomedial border about 5 cm in front of the occipital pole. It extends slightly on the superolateral surface.
    f. A little below the genu, there are two small anterior and posterior ***paraolfactory sulci***.
3. *Gyri on the medial surface*
    a. ***Cingulate gyrus*** lies between the corpus callosum and the cingulate sulcus. Its posterior part is bounded above by the ***suprasplenial sulcus*** and is divided into anterior and posterior parts.
    b. The U-shaped gyrus around the end of the central sulcus is the ***paracentral lobule***. It is usually divided into anterior and posterior parts.
    c. The area between the cingulate gyrus and the superomedial border in front of the paracentral lobule is called the ***medial frontal gyrus***.
    d. The quadrangular area between the suprasplenial sulcus and the superomedial border is called the ***precuneus***.
    e. The triangular area between the parieto-occipital sulcus (above) and the calcarine sulcus (below) is called the ***cuneus***.
    f. A narrow strip between the splenium and the stem of the calcarine sulcus is the ***isthmus***.
    g. ***Paraterminal gyrus*** lies just in front of the lamina terminalis.
    h. ***Paraolfactory gyrus*** lies between the anterior and posterior paraolfactory sulci.

Sulci and Gyri on the Orbital Surface (Fig. 11.5)

1. Parallel to the medial orbital border, there is the ***olfactory sulcus***; between these two, there is the ***gyrus rectus***. The rest of the orbital surface is subdivided by an H-shaped sulcus into *anterior, posterior, medial and lateral* ***orbital gyri***.
2. The stem of the lateral sulcus lies deep between the temporal pole and orbital surface.

Sulci and Gyri on the Tentorial Surface (Fig.11.5)

This area presents two sulci running anteroposteriorly. The medial one is the ***collateral sulcus***, and the lateral is the ***occipitotemporal sulcus***. On the medial side of the temporal pole, there is the ***rhinal sulcus***.

The gyri are as follows:

1. The part medial to the rhinal sulcus is the ***uncus***.
2. The part medial to the collateral sulcus is the ***parahippocampal gyrus***. Its posterior part is limited medially by the calcarine sulcus. It is joined to the cingulate gyrus through the isthmus.
3. The part lateral to the collateral sulcus is divided into ***medial and lateral occipitotemporal gyri*** by the ***occipitotemporal sulcus***.
4. ***Lingual gyrus*** lies between parahippocampal gyrus and occipital pole.

Types of the Cerebral Cortex

Allocortex (archipallium): It is the original olfactory cortex, and is represented by rhinencephalon (piriform area and hippocampal formation). Structurally, it is simple and is made up of only three layers.

Paleocortex or paleopallium: It is intermediate in development. It includes cingulate gyrus.

Isocortex (neopallium): It is the lately acquired cortex, containing various centres other than those for smell. Structurally, it is thick and six layered. It is subdivided into the following:

a. Granular cortex (koniocortex or dust cortex). It is basically a sensory cortex.
b. Agranular cortex. This is the motor cortex.

FUNCTIONAL OR CORTICAL AREAS OF CEREBRAL CORTEX

Functionally, the cortex is divided into number of areas by many neurobiologists. **Brodmann's areas** are taken normally according to whom there are 200 areas.

Types of Cortical Areas

There are three basic functional divisions of cerebral cortex (Table 11.2):

1. ***Motor areas:*** They control motor activity and give rise to corticospinal and corticonuclear fibres.
2. ***Sensory areas:*** In these areas receive afferent sensory fibres from thalamus and subthalamic nuclei.
3. ***Association areas:*** They are responsible for modification of motor activities, interpretation of sensory inputs, intellect, emotions and so on.

Note: The motor and sensory functions also overlap in the same region of cortex. If the motor function is predominant, it is known as motor-sensory (Ms) and where sensory function is predominant, it is called sensorimotor (Sm).

Motor Areas (Figs 11.6 to 11.8)

Primary Motor Area (Area 4)

It is located in the precentral gyrus, including the anterior wall of central sulcus, and in the anterior part of paracentral lobule on the medial surface of cerebral hemispheres. This corresponds to area 4 of Brodmann.

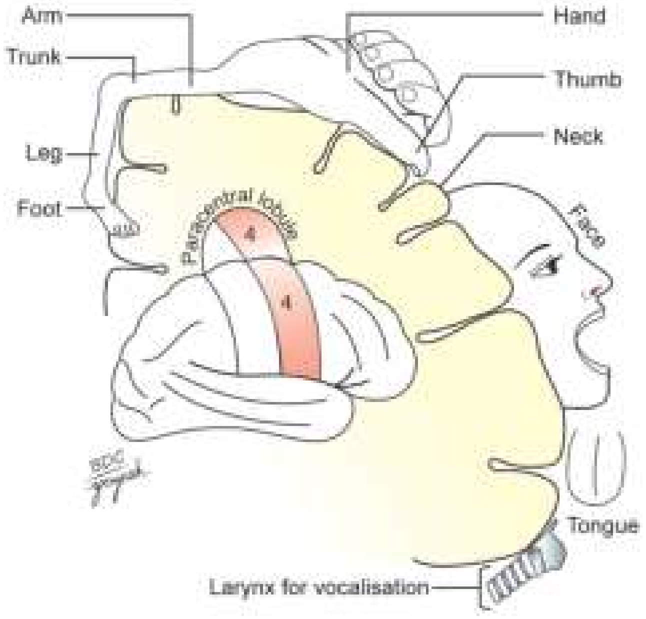

Arm
Trunk
Leg
Foot
Paracentral lobule
4
4
Hand
Thumb
Neck
Face
Tongue
Larynx for vocalisation
BDC

Fig. 11.6: Motor homunculus on the precentral gyrus

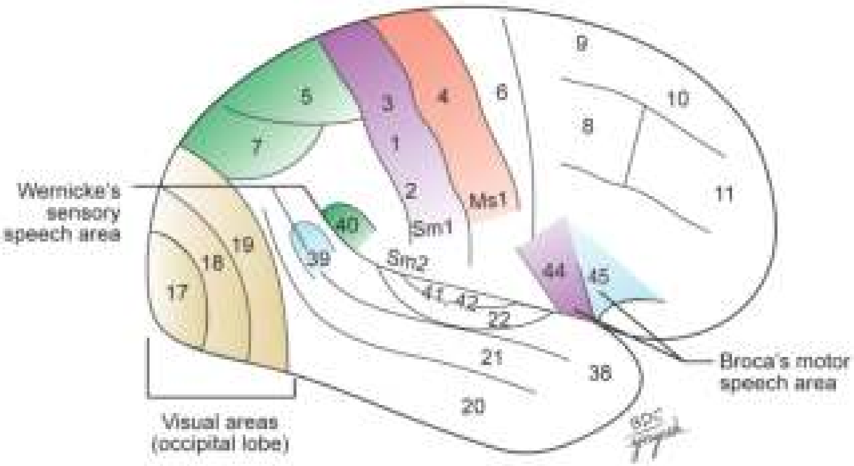

5
3
4
6
9
10
8
7
1
11
2
Ms1
Wernicke's sensory speech area
40
Sm1
39
19
18
Sm2
44
45
17
41 42
22
21
38
Broca's motor speech area
20
Visual areas (occipital lobe)
BDC

Fig. 11.7: Functional areas of the superolateral surface of cerebral hemisphere

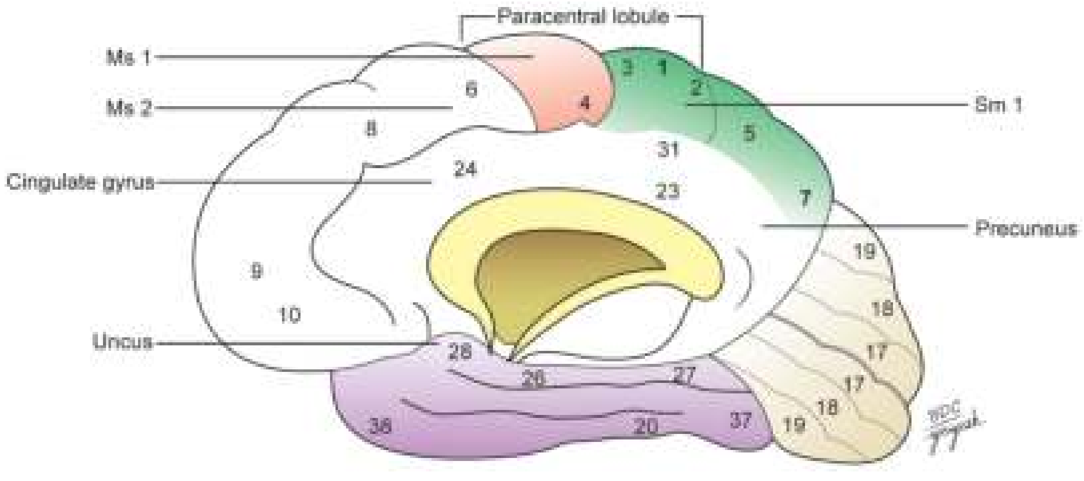

Paracentral lobule
Ms 1
Ms 2
6
4
3
1
2
Sm 1
8
5
24
31
Cingulate gyrus
23
7
Precuneus
19
9
18
10
Uncus
28
17
26
27
17
18
38
20
37
19
BDC

Fig. 11.8: Functional areas of the medial surface of cerebral hemisphere

TABLE 11.2: Functional areas of the cerebral cortex

Lobe	*Area*	*Area no.*	*Location*	*Function*	*Effect of lesion*
Frontal	Motor	4	Precentral gyrus and paracentral lobule	Controls voluntary activities of the opposite half of body Body represented upside down except face	Contralateral paralysis and Jacksonian fits
	Premotor	6	Posterior parts of superior, middle and inferior frontal gyri	Controls extrapyramidal system	Often mixed with pyramidal effect
	Frontal eye field	6, 8	Posterior part of middle frontal gyrus	Controls horizontal conjugate movements of the eyes	Horizontal conjugate movements are lost
	Motor speech (Broca's area)	44, 45	Pars triangularis and pars opercularis	Controls the spoken speech	Aphasia (motor)
	Prefrontal	9, 10, 11, 12	The remaining large, anterior part of frontal lobe	Controls emotions, concentration, attention initiative and judgement	Loss of orientation
Parietal	Sensory (somesthetic)	3, 1, 2	Postcentral gyrus and paracentral lobule	Perception of exteroceptive (touch, lobule pain and temperature) and proprioceptive impulses Body represented upside down except face	Loss of appreciation of the impulses received
	Sensory association	5, 7	Between sensory and visual areas	Stereognosis and sensory speech	Astereognosis and sensory aphasia
		39, 40	Inferior part of parietal lobule as angular gyrus and supramarginal gyrus	Sensory speech area Language comprehension Emotional responses	Sensory aphasia
Occipital	Visuosensory area or striate	17	In and around the postcalcarine sulcus	Reception and perception of the isolated visual impressions of colour, size, form, motion, illumination and transparency Macular area has largest representation	Homonymous hemianopia with macular sparing
	Visuopsychic area, parastriate and peristriate	18, 19	Surround the striate area	Correlation of visual impulses with past memory and recognition of objects seen, and also the depth	Visual agnosia
Temporal	Auditosensory	41, 42	Heschl's gyrus (situated within the lateral sulcus, on the superior surface of the temporal lobe)	Reception and perception of isolated auditory impressions of loudness, quality and pitch	Impaired hearing
	Auditopsychic (Wernicke's area)	22	Superior temporal gyrus of the dominant cerebral hemisphere	Correlation of auditory impressions with past memory and identification (interpretation) of the sounds heard	Auditory agnosia Sensory aphasia

Note: The inferior aspect of the supramarginal gyrus within the inferior parietal lobule of the dominant hemisphere corresponds to Wernicke's area, which extends along the posterior aspect of the superior temporal gyrus. The functionally defined Wernicke's area is not clearly delineated anatomically, but corresponds to Broca's area 22 (*Reference*: Gray's Anatomy, 42nd ed.). Some authors consider areas 39, 40 and 22 together as Wernicke's area.

Function: The primary motor area controls the muscles on the opposite side of body.

The contralateral half of the body is represented as upside down, except the face. The pharyngeal region and tongue are represented in the most ventral and lower part of precentral gyrus, followed by the face, hand, arm, trunk and thigh. The leg, foot and perineum are on the medial surface of hemisphere in the paracentral lobule.

Note: The primary motor area shows the significant ipsilateral control of most of the muscles of the head and axial muscles of the body.

The size of the cortical motor area for a particular part of the body is determined by the functional importance of the part and its need for sensitivity and intricacy of the movements of that region. The area for the face, especially the *larynx and lips*, is, therefore, disproportionately large and a large area is assigned to the hand particularly the thumb and index finger. Movements of joints are represented rather than individual muscles.

Premotor Area *(Area 6)*

This area coincides with the Brodmann's area 6 and is situated anterior to motor area in the superolateral and medial surfaces of the hemisphere (Figs 11.7 and 11.8).

Function: The premotor area contributes to motor function by its direct contribution to the pyramidal and other descending motor pathways and by its influence on the primary motor cortex.

Note: In general, the primary motor area is the cortex in which execution of movements originates and relatively simple movements are maintained. In contrast, the premotor area programmes skilled motor activity and thus directs the primary motor area in its execution.

The premotor and primary motor areas are together referred to as the ***primary somatomotor area*** (Ms1). Both these areas give origin to corticospinal and corticonuclear fibres and receive fibres from cerebellum after relay in ventral intermediate nucleus of thalamus.

Supplementary Motor Area (Ms2)

It is predominantly motor in function. This motor area is in the part of area 6 that lies on the medial surface of the hemisphere anterior to the paracentral lobule. Different parts of body are represented within this area. It differs from the main motor area in that its stimulation produces bilateral movements (Fig. 8.8). Its function is to control complex movements which require sequential organisation.

Motor Speech Area of Broca (Areas 44 and 45)

(French Neurologist, 1824–1840)

The Broca's area occupies the opercular and triangular portions of the inferior frontal gyrus corresponding to the areas 44 and 45 of Brodmann. This is present on the left side in 98% of right-handed persons. In 70% of left-handers, it is again present in the left hemisphere. Only in 30%, it is situated in the right hemisphere.

Frontal Eye Field (Areas 8)

It lies in the middle frontal gyrus just anterior to precentral gyrus. It is the lower part of area 8 of Brodmann on the lateral surface of cerebral hemisphere, extending slightly beyond that area. Electrical stimulation of this area causes deviation of both the eyes to the opposite side. This is called conjugate movements of eyes. Movements of the head and dilatation of pupil may also occur. This area is connected to the cortex of occipital lobe which is concerned with vision.

Prefrontal Cortex (Areas 9, 10, 11, 12)

Prefrontal cortex is a large area lying anterior to the precentral area. It includes the superior, middle, and inferior frontal gyri, medial frontal gyrus, orbital gyri and anterior half of the cingulate gyrus. These include Brodmann's areas 9, 10, 11 and 12. This area is connected to other areas of the cerebral cortex, corpus striatum, thalamus and hypothalamus. It is also connected to cerebellum through the pontine nuclei. It controls emotions concentration, attention, initiative and judgement. It has reciprocal connections with thalamic dorsomedial nucleus, hypothalamus, and limbic system.

CLINICAL NEUROANATOMY

- Destructive lesion of primary motor area 4 results in voluntary paresis of the affected part of body. Spastic voluntary paralysis of the opposite side of body characteristically follows, if the lesion spreads beyond area 4 or that interrupts projection fibres in the medullary centre or internal capsule. Irritative lesion of the motor area leads to focal convulsive movements of the corresponding part of body, referred to as ***Jacksonian epilepsy***.
- Lesion of supplementary motor area 6 leads to apraxia and akinesia. This is the condition that involves difficulty in performing the skilled movements once learnt, in the absence of paralysis, ataxia or sensory loss. When the disability affects writing, it is called *agraphia*.
- *Frontal eye field:* Destruction of this area causes conjugate deviation of the eyes towards the side of lesion. The patient cannot voluntarily move his eyes in the opposite direction, but this movement occurs involuntarily when he observes an object moving across the field of vision.
- *Speech area:* Lesion of Broca's area on the dominant side of hemisphere causes expressive aphasia. It is characterised by hesitant and distorted speech with relatively good comprehension.
- A lesion involving language areas *(Wernicke's area* and *Broca's area)* leads to receptive aphasia. In this condition, auditory and visual comprehension of language that is naming of objects and repetition of a sentence spoken by the examiner are all defective (Fig. 8.8).
- A lesion involving Wernicke's area and superior longitudinal fasciculus or arcuate fasciculus results in *jargon aphasia* in which speech is fluent but unintelligible jargon.
- Voluntary smile in a stroke patient will accentuate the asymmetry. A genuine smile which uses only extrapyramidal pathways, will be symmetrical and there will be no asymmetry for the duration of the smile. One needs to remember that motor cortex is required only for voluntary moment.

Sensory Areas (Figs 11.7 to 11.9)

First Somesthetic Area (Areas 3, 1, and 2)

First somesthetic (general sensory) area is also called *first somatosensory area* (Sm1). It occupies postcentral gyrus on the superolateral surface of the cerebral hemisphere and posterior part of paracentral lobule on the medial surface. It corresponds to areas 3, 1 and 2 of Brodmann.

The representation of the body in this area corresponds to that in the motor area that is contralateral half of body is represented upside down except the face.

The ventral posterior nucleus of thalamus is the main source of afferent fibres for the sensory area. This thalamic nucleus is the site of termination of all the fibres of the medial lemniscus. Most of the fibres of the spinothalamic and trigeminothalamic tracts carrying

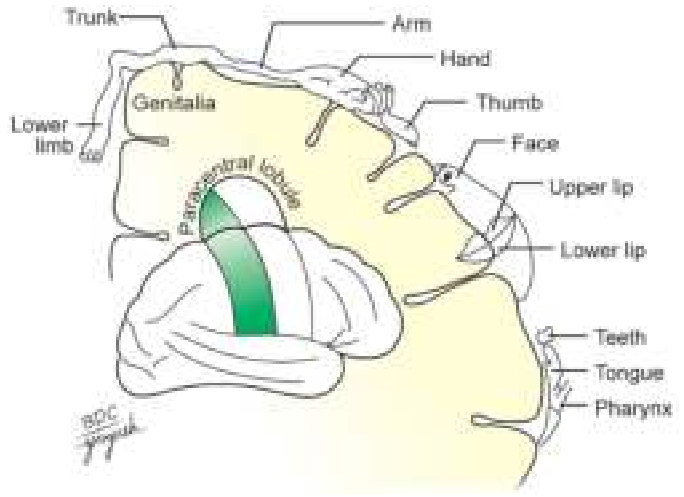


Fig. 11.9: Sensory homunculus of the postcentral gyrus

fibres for cutaneous sensibility end in anterior part of the area and those for deep sensibility end in the posterior part.

Note: The area of the cortex that receives sensations from a particular part of body is not proportional to the size of that part, but rather to the intricacy of sensations received from it. Thus, the thumb, fingers, lips and tongue have a disproportionately large representation. The different sensations, i.e. cutaneous and proprioceptive, are represented in different parts within sensory area.

Second Somesthetic Area

Second somesthetic area, also known as second *somatosensory area* (Sm2). This is situated in the superior lip of the posterior ramus of lateral sulcus with postcentral gyrus. The parts of body are represented bilaterally.

Somesthetic Association Cortex *(Areas 5 and 7)*

Somesthetic association cortex is mainly in the superior parietal lobule on the superolateral surface of the hemisphere and in the precuneus on the medial surface. It coincides with areas 5 and 7 of Brodmann. This receives afferents from first sensory area and has reciprocal connection with dorsal tier of nuclei of lateral mass of thalamus. Data pertaining to the general senses are integrated, permitting a comprehensive assessment of the characteristic of an object held in hand and its identification without visual aid.

Receptive Speech Area of Wernicke

(German Neurologist, 1848–1903)

This is also known as *sensory language area*. It consists of auditory association cortex and of adjacent parts of the inferior parietal lobule.

CLINICAL NEUROANATOMY

- First somesthetic or general sensory area (areas 3, 1 and 2 of Brodmann): When this part of cortex is the site of destructive lesion, a crude form of awareness persists for the sensation of pain, heat and cold on the opposite side of lesion. There is poor localisation of stimulus. There is loss of discriminative sensations of fine touch, movements and position of part of the body.
- Somesthetic association cortex (superior parietal lobule) areas 5 and 7 of Brodmann: A lesion in this area leads to defect in understanding the significance of sensory information, which is called ***agnosia***. A lesion that destroys a large portion of this association cortex causes tactile agnosia and ***astereognosis*** which are closely related. This is the condition when a person is unable to recognize the objects held in the hand, while the eyes are closed. He is unable to correlate the surface, texture, shape, size and weight of the object or to compare the sensations with previous experience.

Areas of Special Sensations

Vision *(Areas 17, 18 , and 19)*

The ***visual area*** is located above and below the calcarine sulcus on the medial surface of occipital lobe. It corresponds to **area 17** of Brodmann. The visual area is also called the striate area because the cortex here contains the *line of Gennari*, which is just visible to the unaided eye.

The chief source of afferent fibres to area 17 is the *lateral geniculate nucleus* of thalamus by way of geniculocalcarine tract.

Area 17 constitutes the first visual area. It is continuous both above and below with **area 18** and beyond this with **area 19** of Brodmann which are also known as v***isual association or psychovisual areas***. Since fibres of geniculocalcarine tract (optic radiation) terminate in these regions also, therefore, these areas are regarded as second and the third visual areas, respectively.

The role of the second and third visual areas includes among other complex aspects of vision, the relating of present to past visual experience, with recognition of what is seen and appreciation of its significance. The three areas are linked together by association fibres. The visual areas give efferent fibres which reach frontal eye field.

Hearing *(Areas 41, and 42)*

The ***auditory*** **(acoustic)** ***area*** lies in the temporal lobe. Most of it is concealed as it lies in that part of superior temporal gyrus which forms inferior wall of the posterior ramus of lateral sulcus. It corresponds with areas ***41 and 42 of Brodmann***.

The *medial geniculate* body of the thalamus is the principal source of fibres ending in the auditory cortex with these fibres constituting the auditory radiation. There is spatial representation in the auditory area with respect to pitch of sounds. Impulses of low frequencies impinge on anterolateral part of area and impulses of high frequencies get heard on the posteromedial part.

Cortex gets afferents from both ears. Body receives information that originates mainly in the organ of Corti of opposite side, the incomplete decussation of ascending pathways ensures a substantial input from the ear of same side as well.

The auditory radiation does not only end in first auditory area but extends to neighbouring area as well, that is known as ***auditory association area*** or second auditory area. This area lies behind the first auditory area in superior temporal gyrus. It corresponds to ***area*** **22** of Brodmann on the lateral surface of superior temporal gyrus. This region of the cortex is also known as ***Wernicke's area*** and is of major importance in language functions.

Taste (Area 43)

The ***taste area*** (gustatory area) is located in dorsal wall of posterior ramus of lateral sulcus, with extension into insula and corresponds to ***area 43*** of Brodmann. It places the taste area adjacent to first sensory area of cortex for tongue and pharynx. Its location is similar to second somesthetic area.

Smell

Ends in ***pyriform lobe***.

Vestibular Area

Vestibular area is situated close to the part of postcentral gyrus concerned with sensations of face.

CLINICAL NEUROANATOMY

Special sensory areas

a. Primary visual area 17: Lesion of this area, leads to loss of vision in the visual field of the opposite side – homonymous hemianopia.
b. Auditory area:
    - Primary auditory areas 41 and 42: A unilateral lesion involving the auditory area causes diminution in the acuity of hearing in both ears and the loss is greater in the opposite ear. However, the impairment is slight because of the bilateral projection to the cortex and the deficit is difficult to detect by clinical tests.
    - Auditory association cortex or secondary area 22. In lesions of this area, interpretation of the sounds is lost.

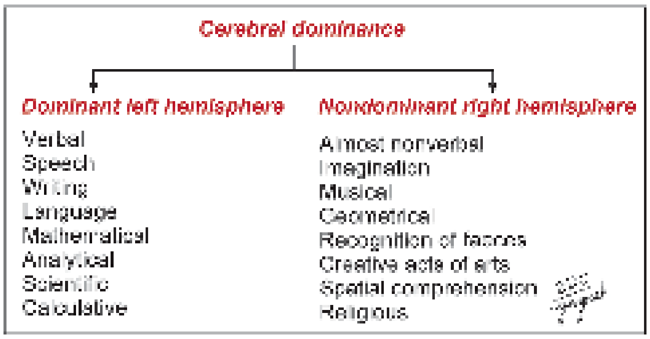
Aphasia is a disorder of language (speech) that results from damage to that portion of the brain which are responsible for language (Wernicke's area and Broca's area). It usually occurs suddenly often as the result of a stroke or head injury. But it may develop slowly as in the case of a brain tumour.

Table 11.3 depicts summary of functions and effects of damage of lobes of brain.

Cerebral Dominance

One cerebral hemisphere dominates the other one in relation to handedness, speech, perception of language and spatial judgement. In 80–95% subjects, the left hemisphere dominates the right one. The dominant lobe contains the Broca's motor speech area. Since left hemisphere controls the right half of the body, all these subjects are right-handed. The left hemisphere is verbal speech, writing, mathematical, analytical, scientific, calculative and has direct link to consciousness (Flowchart 11.3).

Flowchart 11.3: Lateralisation of functions in the dominant and nondominant hemispheres



The right hemisphere is almost non-verbal, active in understanding geometrical figures imaginative, artistic, religious, and important for temporal synthesis and spatial comprehension. It helps in recognition of faeces, figures and appreciating music.

Localisation of speech on left side in 70% of left handed and 98% of right-handed is well known. Association of negative emotions with right prefrontal activity and of positive emotions with left prefrontal activity is also known.

Functional asymmetry in a structurally symmetrical structure is a great and ingenious way of economising on neural tissue. It practically doubles the capabilities of the brain.

Note: Mahatma Gandhi (father of the nation), Bill Clinton, Bill Gates, Amitabh Bachchan and Abhishek Bachchan, are all left-handed.

Competency:

AN64.1 Describe and identify the microanatomical features of spinal cord, cerebellum and cerebrum.

Microanatomy/histology of cerebrum is described here. For others see the appropriate chapters.

HISTOLOGY OF CEREBRUM

It is characterised by *heterotypical cortex*, i.e. histological structure differs in various regions of cerebral cortex. The outermost covering of the cerebral cortex is the pia mater which is the innermost meningeal layer. It carries capillaries to the grey matter. The cerebral cortex contains variety of cells. These are arranged in layers with one or more cell types predominant in each layer. The horizontal fibres are associated with each layer and give it a laminated appearance. From superficial to deep, the following six layers are seen (Plate 11.2):

1. *Molecular layer* consists of a few fibres and some spindle-shaped or stellate cells.
2. *Outer granular layer* contains small cells, triangular in shape, with an apex directed peripherally and the base

Plate 11.2: Histology of cerebrum

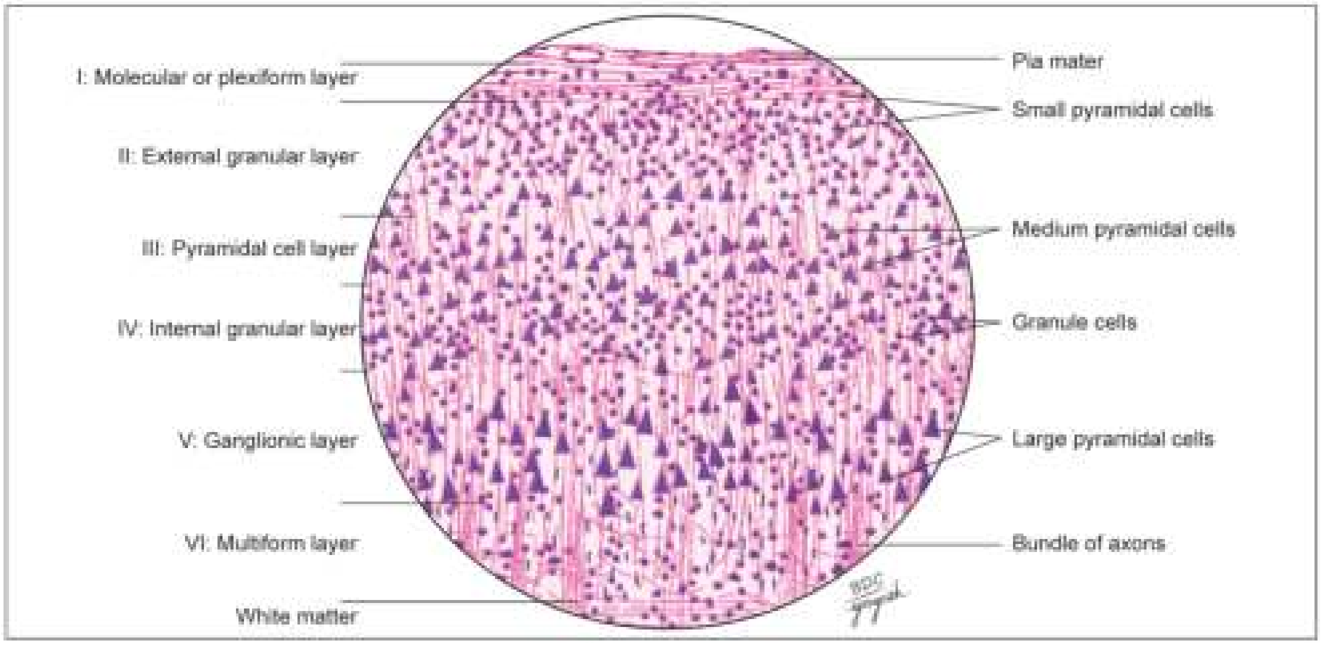


TABLE 11.3: Summary of functions and effects of damage of lobes of brain

Lobes of brain	*Functions*	*Effects of damage*
Frontal	Personality, emotional control, social behaviour, contralateral motor control, micturition, judgement thinking, planning behaviour, executive function, language production (Broca's area)	Lack of initiation, antisocial behaviour, impaired memory and incontinence
Parietal (non-dominant)	Spatial orientation, recognition of faces, appreciation of music and figures	Spatial disorientation, non-recognition of faces
Parietal (dominant)	Language, calculation, analytical, logical, and geometrical	Dyscalculia, dyslexia, apraxia (inability to do complex movements) and agnosia (inability to recognize)
Temporal (non-dominant)	Auditory perception, pitch perception, non-verbal memory, smell and balance	Reception aphasia and impaired musical skills
Temporal (dominant)	Language, verbal memory and auditory perception (Wernicke's area)	Dyslexia, verbal memory impaired and receptive aphasia
Occipital	Visual reception and interpretation	Visual loss and visual agnosia

directed inwards. The axons leave from the basal part of the cell. A few stellate cells are also seen.

3. *Outer pyramidal layer* has similar cells as outer granular layer, but the cells are distinctly larger than those of the outer granular layer.
4. *Inner granular layer* contains cells which are larger than outer pyramidal cells, but have large number of stellate cells between them.
5. *Inner pyramidal layer* contains cells which are triangular in shape and are the largest cells of the cerebral cortex, especially in the motor cortex where these are termed as the Betz cells.
6. *Fusiform layer* or *polymorphous layer* contains mainly fusiform cells with a few stellate cells. No pyramidal cells are seen in this layer.

The granular cell layers are *afferent* in connection and the pyramidal cell layers are *efferent* in nature. The pyramidal cells are more pronounced in the motor areas, whereas the granular cells are more conspicuous in the sensory areas of the brain. In between the nerve cells are the nerve fibres of these cells and capillaries. The neuroglial elements are protoplasmic astrocytes, oligodendroglia and microglia.

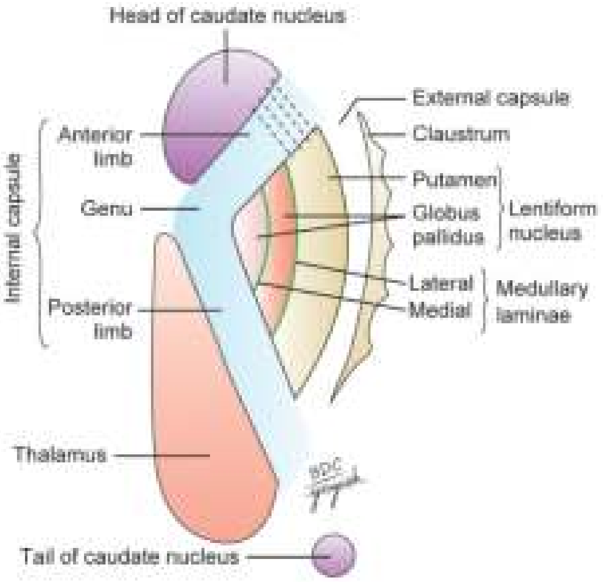
Competency:

AN62.4 Enumerate parts and major connections of basal ganglia/nuclei and limbic lobe. Also explain the anatomical basis of Parkinson's disease, chorea, athetosis and ballismus.

Limbic lobe/system is described in Chapter 12.

BASAL NUCLEI

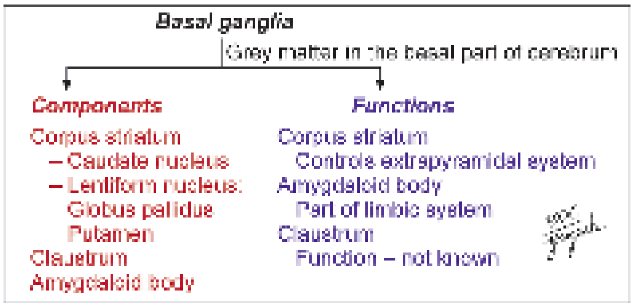
The basal nuclei are subcortical and, intracerebral masses of grey matter forming important parts of the extrapyramidal system (Fig. 11.10, Flowchart 11.4).



Head of caudate nucleus
External capsule
Claustrum
Internal capsule
Anterior limb
Genu
Posterior limb
Putamen
Globus pallidus
Lentiform nucleus
Lateral
Medial
Medullary laminae
Thalamus
Tail of caudate nucleus

Fig. 11.10: Horizontal section through corpus striatum, thalamus and internal capsule

Flowchart 11.4: Basal ganglia



Basal ganglia

Grey matter in the basal part of cerebrum

Components

Corpus striatum
  – Caudate nucleus
  – Lentiform nucleus:
    Globus pallidus
    Putamen
Claustrum
Amygdaloid body

Functions

Corpus striatum
  Controls extrapyramidal system
Amygdaloid body
  Part of limbic system
Claustrum
  Function – not known

Components

The basal nuclei include the following (Fig. 11.10):

1. *Corpus striatum*, which is partially divided by the internal capsule into two nuclei:
   a. *Caudate nucleus.*
   b. *Lentiform nucleus.*
2. *Amygdaloid body* forms a part of the limbic system.
3. *Claustrum.*

The four nuclei (caudate, lentiform, amygdaloid and claustrum) are joined to the cortex at the anterior perforated substance.

CORPUS STRIATUM

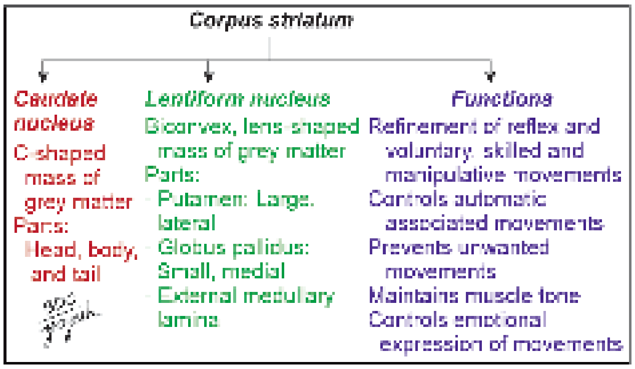
Corpus striatum (Latin *striped body*) comprises the caudate nucleus and lentiform nucleus.

Corpus striatum is subdivided by the fibres of internal capsule into (Flowchart 11.5):

1. Caudate nucleus
2. Lentiform nucleus: It is divided into a lateral part, the *putamen*, and a medial part, the *globus pallidus*.

Note: The caudate and lentiform nuclei are interconnected by a few bands of grey matter below the anterior limb of the internal capsule. The bands give it a striped appearance, hence the name.

Flowchart 11.5: Corpus striatum



Corpus striatum

Caudate nucleus

C-shaped mass of grey matter
Parts:
  Head, body, and tail

Lentiform nucleus

Biconvex, lens-shaped mass of grey matter
Parts:
- Putamen: Large, lateral
- Globus pallidus: Small, medial
- External medullary lamina

Functions

Refinement of reflex and voluntary, skilled and manipulative movements
Controls automatic associated movements
Prevents unwanted movements
Maintains muscle tone
Controls emotional expression of movements

Caudate Nucleus

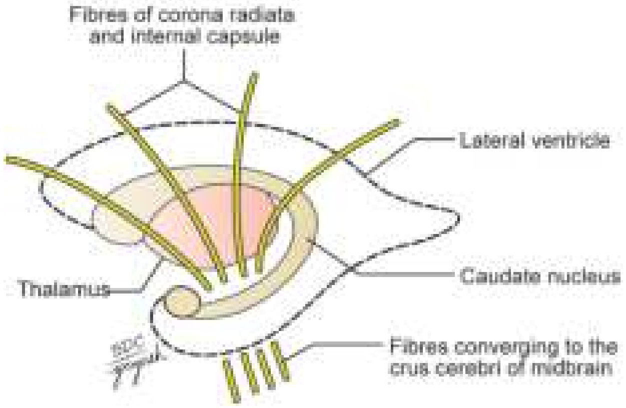
It is a C-shaped or comma-shaped nucleus which is surrounded by the lateral ventricle. The concavity of 'C' encloses the thalamus and the internal capsule (Fig. 11.11).

The nucleus has a head, a body, and a tail.

1. ***Head:*** The head forms the floor of the anterior horn of the lateral ventricle, and the medial wall of the anterior limb of the internal capsule. Bands of grey matter connect it to the putamen across the anterior limb of the internal capsule near the anterior perforated substance.
2. ***Body:*** The body forms the floor of the central part of the lateral ventricle, and lies medial to the posterior limb of the internal capsule. It is separated from the thalamus by the stria terminalis and the thalamostriate vein. Superiorly, it is related to the fronto-occipital bundle and the corpus callosum.
3. ***Tail:*** The tail forms the roof of the inferior horn of the lateral ventricle, and ends by joining the amygdaloid body at the temporal pole. It is related medially to the stria terminalis, laterally to the tapetum, and superiorly to the sublentiform part of the internal capsule and to the globus pallidus.

Lentiform Nucleus

This is a large, lens-shaped (biconvex) nucleus, forming the lateral boundary of the internal capsule. It lies beneath the insula and the claustrum.



Fibres of corona radiata and internal capsule
Lateral ventricle
Caudate nucleus
Thalamus
Fibres converging to the crus cerebri of midbrain

Fig. 11.11: Relations of caudate nucleus to lateral ventricle, thalamus and internal capsule seen in lateral view

The lentiform nucleus has three surfaces:

1. The *lateral surface* is convex. It is related to the external capsule – the claustrum, the extreme capsule, insula, and is grooved by the *lateral striate arteries*.
2. The *medial surface* is more convex. It is related to the internal capsule – the caudate nucleus and the thalamus.
3. The *inferior surface* is related to the sublentiform part of the internal capsule which separates it from the optic tract, the tail of the caudate nucleus, and the inferior horn of the lateral ventricle. The surface is grooved by the anterior commissure just behind the anterior perforated substance.

The lentiform nucleus is divided into two parts by a thin lamina of white matter.

The larger lateral part is called the *putamen* (Latin *to cut).* Structurally, it is similar to the caudate nucleus and contains small cells.

The smaller medial part is called the *globus pallidus*. It is made up of large (motor) cells.

Morphological Divisions of Corpus Striatum

1. The *paleostriatum* is the older and primitive part. It is represented by the globus pallidus (pallidum).
2. The *neostriatum* is more recent in development. It is represented by the caudate nucleus and the putamen of the lentiform nucleus. The neostriatum is often called the striatum.

Connections of Corpus Striatum

The caudate nucleus and putamen are afferent nuclei, while the globus pallidus is the efferent nucleus, of the corpus striatum (Fig. 11.12). The connections are shown in Table 11.4.

Functions of Corpus Striatum

The corpus striatum performs important role in the extrapyramidal system. It performs the following functions:

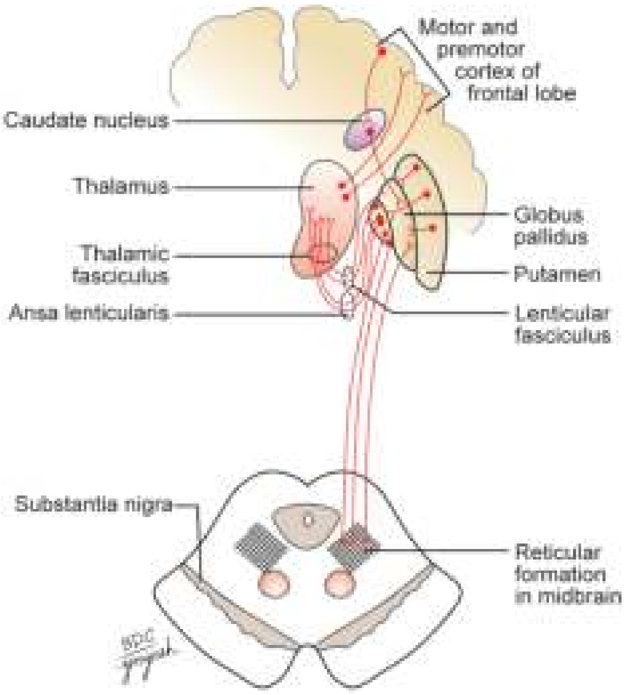


Fig. 11.12: Connections of corpus striatum

1. Refinement of reflex and voluntary movements.
2. Refinement of skilled and manipulative movements of the body. For example, threading a needle.
3. Controls automatic associated movements such as swinging of arms during walking.
4. Prevents unwanted movements.
5. Maintains muscle tone.
6. Controls emotional expression of movements.

CLAUSTRUM

It is saucer-shaped nucleus situated between the putamen and the insula, with which it is coextensive. Inferiorly, it is thickest and continuous with the anterior perforated substance. Its connections and functions are not known.

TABLE 11.4: Connections of the corpus striatum

Nucleus	*Afferents*	*Efferents*
A. Caudate nucleus and putamen	• Corticostriate fibres from cerebral cortex • Thalamostriate fibres • Nigrostriate fibres from substantia nigra	• Striatopallidal fibres to globus pallidus • Few fibres to thalamus and substantia nigra
B. Globus pallidus	• Most of the fibres from neostriatum (caudate nucleus + putamen) • Few fibres from – Substantia nigra – Thalamus and subthalamus	Efferent fibres to thalamus, hypothalamus, subthalamus, red nucleus, olivary nucleus, substantia nigra, and reticular nuclei through 1. Ansa lenticularis 2. Fasciculus lenticularis 3. Subthalamic fasciculus

Note:

1. ***Lenticular fasciculus*** (*fasciculus lenticularis*): It carries efferent fibre from the globus pallidus. It passes through the posterior limb of internal capsule. They pass superior to the subthalamic nucleus as lentiform fasciculus and terminates in the thalamus.
2. ***Ansa lenticularis*:** Some efferent fibres from globus pallidus curve around the inferior aspects of posterior limb of internal capsule and form a loop called ansa lenticularis. Its fibres terminate in thalamus, substantia nigra, red nucleus, reticular nuclei, and inferior olivary nucleus.
3. ***Thalamic fasciculus*:** Lenticular fasciculus + Thalamic fibres of ansa lenticularis.
4. ***Subthalamic fasciculus*:** These are fibres connecting globus pallidus and subthalamic nuclei (medial and lateral geniculate bodies).

AMYGDALOID BODY

This is a nuclear mass in the temporal lobe, lying anterosuperior to the inferior horn of the lateral ventricle. Topographically, it is continuous with the tail of the caudate nucleus, but functionally, it is related to the stria terminalis. It is a part of the limbic system (Fig. 11.13). It is continuous with the cortex of the uncus, the limen insulae and the anterior perforated substance.

Afferents: From the olfactory tract.

Efferents: It gives rise to the stria terminalis which ends in the anterior commissure, the anterior perforated substance and in hypothalamic nuclei.

Functions: Emotional control. Controls smell related sexual behavior.

Damage to amygdaloid body if bilateral causes increase in sexual activity and reduced fear.

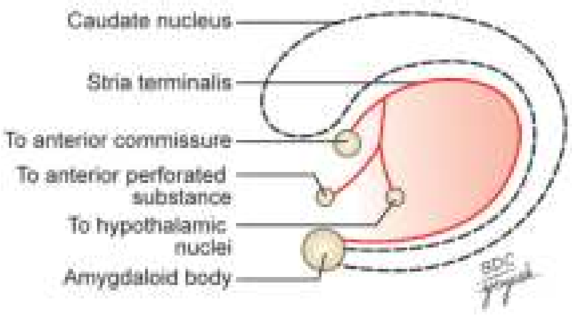


Fig. 11.13: Connections of amygdaloid body

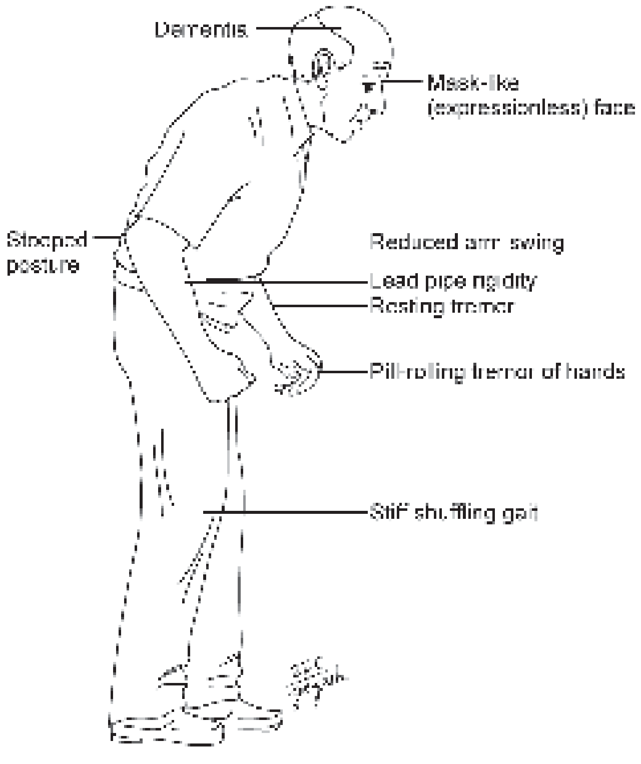


Fig. 11.14: Posture in parkinsonism

CLINICAL NEUROANATOMY

Parkinsonism: Lesions of corpus striatum lead to parkinsonism (Fig. 11.14). Its features are:

a. Hypertonicity or lead pipe rigidity.
b. Loss of automatic associated movements and also of facial expression.
c. Involuntary movements like tremors, choreiform movements, athetoid movements.
d. Continuous writhing movements of trunk and limbs may continue even in sleep. Voluntary movements may be impossible.

L-dopa (a precursor of dopamine) is used as a replacement therapy in parkinsonism because dopamine, the normal neurotransmitter in the striatum, is reduced in these cases. The Nigrostriate fibres are considered important in the genesis of parkinsonism tremor, since its neurons utilize dopamine in the neurotransmission.

Chorea: Chorea means dancing. Chorea is form of involuntary movement characterised by fine random movements of hands and feet. These movements are rather disorganised. This occurs due to disease of caudate nucleus.

Athetosis: It is a form of movement which is slow repetitive and writhing in nature. It is due to lesion of putamen.

Ballismus: This is characterised by irregular movements of trunk, girdles and both the limbs. It is due to disease of subthalamic nucleus.

Neurosurgically, pallidectomy and thalamodectomy have been used with success to control the contralateral tremors in different types of disease of corpus striatum.

Competency:

AN62.3 Describe the white matter of cerebrum. Also describe the effects of damage to corpus callosum and different parts of internal capsule.

DISSECTION

Raise the lower border of the insula, stripping a thin layer of grey matter situated deep to the white matter of insula. This grey matter is known as the claustrum. As the insula is gradually raised, the external capsule and on a deeper plane, a fan-shaped layer of white matter, the corona radiata, are identifiable. Fibres or corona radiata pass on a deeper plane than that of superior longitudinal fasciculus.

To explore the lentiform nucleus, strip the external capsule and identify rounded lentiform nucleus. Dissect the striate branches of the middle cerebral artery on the lateral surface of the lentiform nucleus.

Remove the genu and rostrum of corpus callosum from the cerebral hemisphere, identify the head of the caudate nucleus and the anterior part of the corona radiata emerging from between the caudate and the lentiform nuclei. Identify the anterior commissure and trace its fibres reaching till the temporal lobe.

Internal Capsule

To expose the internal capsule, remove the lentiform nucleus as it forms the lateral boundary of the internal capsule. It is difficult to separate as many fibres of internal capsule enter the lentiform nucleus. Some fibres form two medullary laminae and divide the lentiform nucleus into outer dark part – the putamen and two paler inner parts – the globus pallidus. Putamen is continuous with the caudate nucleus. Trace the continuity of the corona radiata with the internal capsule and of the internal capsule with the crus cerebri. The latter part is visible after stripping the optic tract from the lateral side of the internal capsule.

WHITE MATTER OF CEREBRUM

The white matter of the cerebrum consists chiefly of myelinated fibres which connect various parts of the cortex to one another and also to the other parts of the CNS.

TYPES OF FIBRES

The cerebrum contains three types of white fibres (Fig. 11.15):

1. ***Association fibres*** – connect one area with another area of same cerebral hemisphere.
2. ***Commissural fibres*** – connect the corresponding areas of two cerebral hemispheres.
3. ***Projection fibres*** – connect the cerebral cortex with subcortical part of nervous system.

Association (Arcuate) Fibres

These are the fibres that connect different cortical areas of the same hemisphere. These are subdivided into the following two types (Fig. 11.16 and Flowchart 11.6).

Short Association Fibres

These fibres connect adjacent gyri.

Long Association Fibres

These fibres connect more widely separated gyri. Some examples are:

1. *Uncinate fasciculus,* connecting the temporal pole to the motor speech area and the orbital cortex.
2. *Cingulum,* connecting the cingulate gyrus to the parahippocampal gyrus seen on the medial surface.

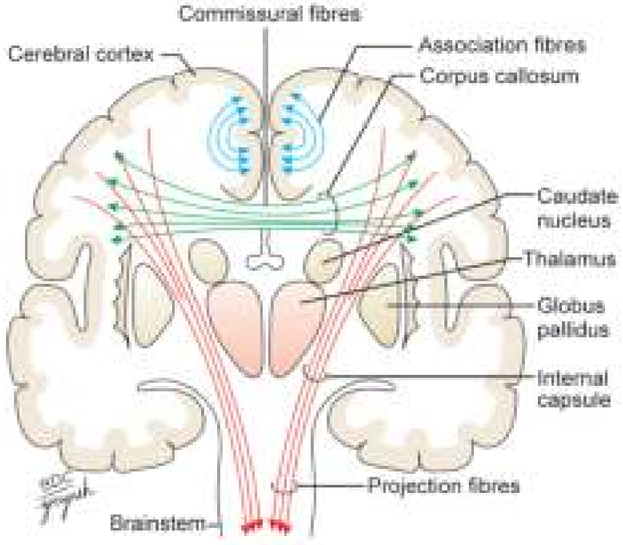
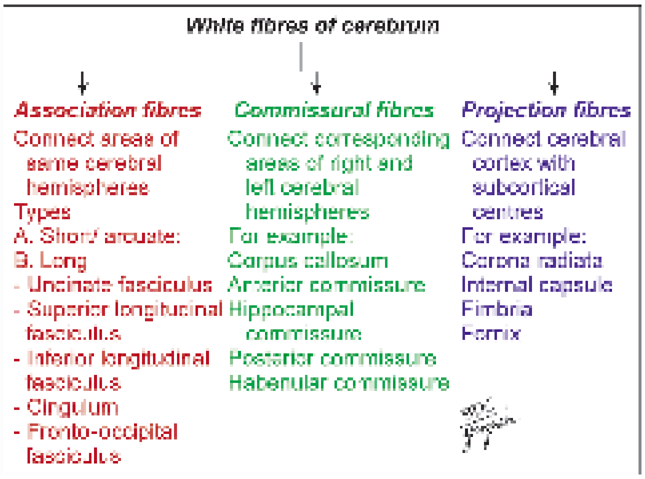

Commissural fibres
Cerebral cortex
Association fibres
Corpus callosum
Caudate nucleus
Thalamus
Globus pallidus
Internal capsule
Projection fibres
Brainstem

Fig. 11.15: White fibres of cerebrum (coronal section of the brain)

Flowchart 11.6: White fibres of cerebrum


White fibres of cerebrum

Association fibres
Connect areas of same cerebral hemispheres
Types
A. Short arcuate:
B. Long
- Uncinate fasciculus
- Superior longitudinal fasciculus
- Inferior longitudinal fasciculus
- Cingulum
- Fronto-occipital fasciculus

Commissural fibres
Connect corresponding areas of right and left cerebral hemispheres
For example:
Corpus callosum
Anterior commissure
Hippocampal commissure
Posterior commissure
Habenular commissure

Projection fibres
Connect cerebral cortex with subcortical centres
For example:
Corona radiata
Internal capsule
Fimbria
Fornix

3. *Superior longitudinal fasciculus,* connecting the frontal lobe to occipital and temporal lobes.
4. *Inferior longitudinal fasciculus,* connecting the occipital and temporal lobes.
5. *Fronto-occipital fasciculi* seen on the medial surface.

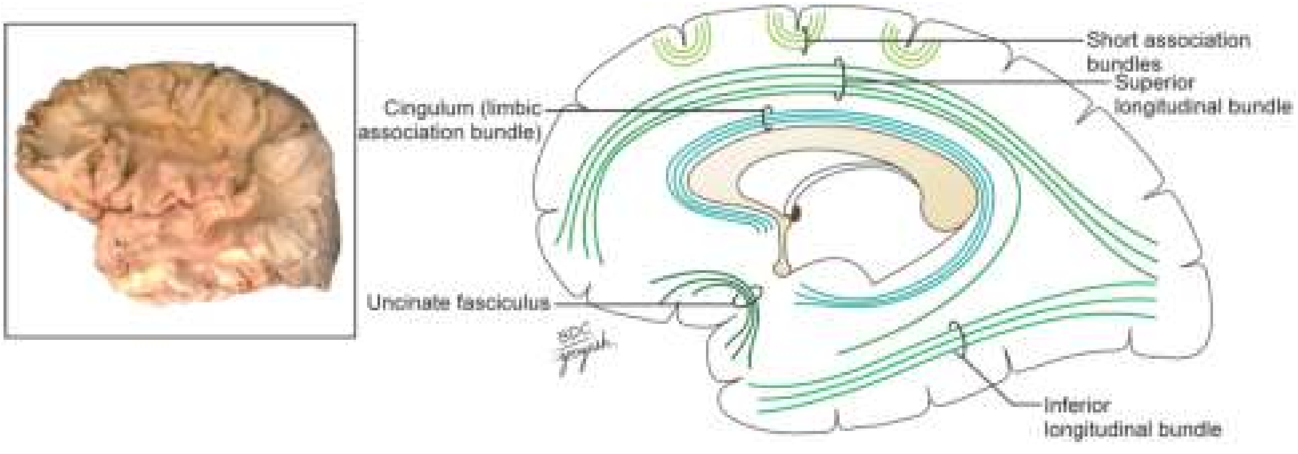

Cingulum (limbic association bundle)
Uncinate fasciculus
Short association bundles
Superior longitudinal bundle
Inferior longitudinal bundle

Fig. 11.16: Association fibres of cerebrum

Commissural Fibres

These are the fibres which connect corresponding parts of the two hemispheres. They constitute the commissures of the cerebrum. They are:

1. *Corpus callosum* connecting the cerebral cortex of the two sides (Figs 11.17a and b).
2. *Anterior commissure,* connecting the archipallia (olfactory bulbs, piriform area and anterior parts of temporal lobes) of the two sides.
3. *Posterior commissure,* connecting the superior colliculi, and also transmitting corticotectal fibres and fibres from the pretectal nucleus to the Edinger-Westphal nucleus of the opposite side.
4. *Commissure of the fornix (hippocampal commissure),* connecting the crura of the fornix and thus the hippocampal formations of the two sides.
5. *Habenular commissure,* connecting the habenular nuclei.
6. *Hypothalamic commissures,* including the anterior hypothalamic commissure of Ganser, the ventral supraoptic commissure of Gudden and the dorsal supraoptic commissure of Meynert.

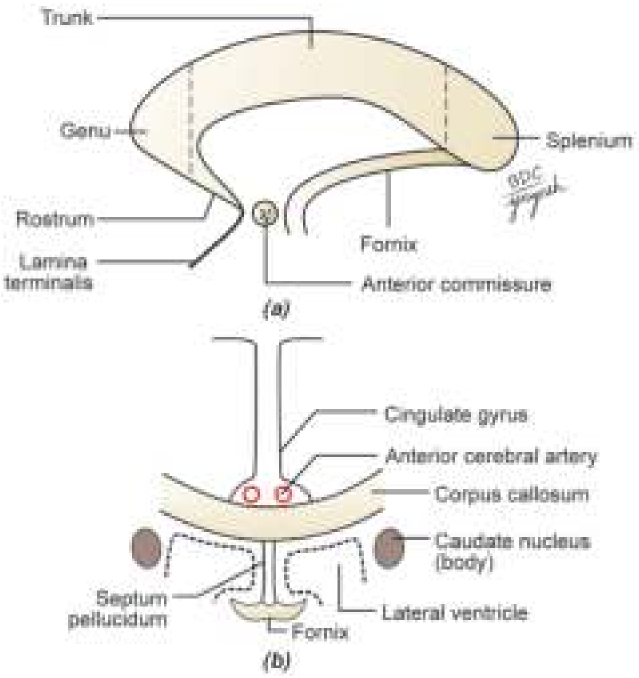
Projection Fibres

They interconnect cerebral cortex with subcortical centres. They include the *corticofugal fibres* which originate in cerebral cortex and go to subcortical centres and the *corticopetal fibres* which reach the cerebral cortex from subcortical centres.

Examples:

1. Corona radiata
2. Internal capsule
3. Fimbria
4. Fornix.

Note: The descending fibres of the lobes of cerebrum converge to form the 'corona radiata' and continue as internal capsule.



Figs 11.17a and b: (a) Parts of corpus callosum and (b) coronal section of the trunk of corpus callosum showing its relations

DISSECTION

Scrape the grey matter between adjacent gyri till the white matter connecting the adjacent gyri is visible. This will expose the short association fibres. Identify the cingulate gyrus on the medial surface of the left hemisphere. Scrape the grey matter of this gyrus till a band of white matter – the cingulum is exposed. Define the extent of cingulum from the anterior end of corpus callosum, around its convex trunk and splenium into the parahippocampal gyrus.

Similarly, scrape the cortex between temporal pole, motor speech area and the orbital cortex to expose uncinate fasciculus. Also expose superior longitudinal fasciculus joining the frontal lobe to the occipital and temporal lobes. Lastly, scrape the grey matter between occipital and temporal lobes to expose the inferior longitudinal fasciculus.

Identify the various parts of the corpus callosum. Remove the fibres of the cingulum and identify the superficial fibres of the genu of corpus callosum passing into the medial aspect of hemisphere. Such fibres of the two sides form the forceps minor.

Expose the band of fibres passing from splenium of corpus callosum towards the superior part of occipital lobe. Trace the fibres of tapetum arising from the trunk and splenium of corpus callosum curving to reach the inferior parts of the occipital and temporal lobes.

Identify the anterior commissure lying just anterior to column of fornix and the interventricular foramen. Examine the posterior commissure situated dorsal to the upper part of aqueduct and inferior to the root of the pineal body. Look for habenular commissure present at the root of the pineal body. Lastly, identify the commissure of the fornix and the hypothalamic commissures.

Lift up a strip of superficial fibres of the genu of corpus callosum and tear these laterally. Identify the intersectioning fibres of corpus callosum and those of the vertically disposed fibres of the corona radiata.

CORPUS CALLOSUM

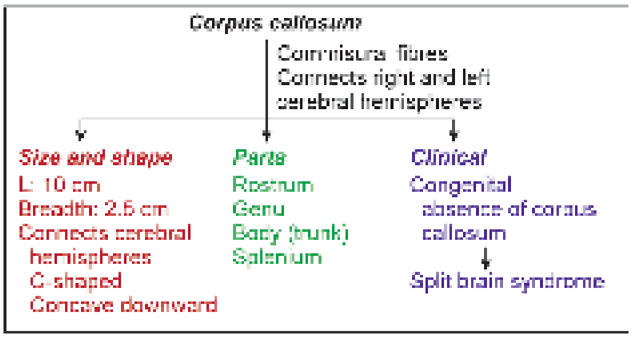
The corpus callosum is the largest commissure of the brain. It connects the two cerebral hemispheres. Since it is the neopallial commissure, it attains enormous size in man (10 cm long, 2.5 cm wide). It contains 150–200 million fibres (axons).

The corpus callosum connects all parts of the cerebral cortex of the two sides, except the lower and anterior parts of the temporal lobes which are connected by the anterior commissure (Figs 11.17a and b and Flowchart 11.7).

Parts of Corpus Callosum

1. ***Genu:*** It is the anterior end. It lies 4 cm behind the frontal pole. It is related anteriorly to the anterior cerebral arteries, and posteriorly to the anterior horn of the lateral ventricle.
2. ***Rostrum:*** It is directed downwards and backwards from the genu, and ends by joining the lamina

Flowchart 11.7: Corpus callosum


Corpus callosum
Commisural fibres
Connects right and left
cerebral hemispheres
Size and shape
L: 10 cm
Breadth: 2.5 cm
Connects cerebral
hemispheres
C-shaped
Concave downward
Parts
Rostrum
Genu
Body (trunk)
Splenium
Clinical
Congenital
absence of corpus
callosum
Split brain syndrome

terminalis, in front of the anterior commissure. It is related superiorly to the anterior horn of the lateral ventricle, and inferiorly to the indusium griseum and the longitudinal striae.

3. ***Trunk or body:*** It is the middle part, between the genu and the splenium.
   a. Its *superior surface* is convex from before backwards and concave from side-to-side. It is related to the anterior cerebral arteries and to the lower border of the falx cerebri. It is overlapped by the cingulate gyrus and is covered by the indusium griseum and the longitudinal striae.
   b. The *inferior surface* is concave from before backwards and convex from side-to-side. It provides attachment to the septum pellucidum and the fornix, and forms the roof of the central part of the lateral ventricle.
4. ***Splenium:*** It is the posterior end forming the thickest part of the corpus callosum. It lies 6 cm in front of the occipital pole. Its *inferior surface* is related to the tela choroidea of the third ventricle – the pulvinar, the pineal body, and the tectum of the midbrain. The *superior surface* is related to the inferior sagittal sinus and the falx cerebri. *Posteriorly,* it is related to the great cerebral vein, the straight sinus and the free margin on the tentorium cerebelli.

Fibres of Corpus Callosum

1. *Rostrum* connects the orbital surfaces of the two frontal lobes.
2. *Forceps minor* is made up of fibres of the genu that connect the two frontal lobes (Fig. 11.18).
3. *Forceps major* is made up of fibres of the splenium connecting the two occipital lobes.
4. *Tapetum* is formed by some fibres from the trunk and splenium of the corpus callosum. The tapetum forms the roof and lateral wall of the posterior horn, and the lateral wall of the inferior horn of the lateral ventricle.

Functional Significance

The corpus callosum helps in coordinating activities of the two hemispheres.

Note: ***Indusium griseum*** is a thin layer of grey matter that covers the superior convex surface of corpus callosum. The pair of ***medial and lateral longitudinal stria*** (white fibres) lie within the indusium griseum.

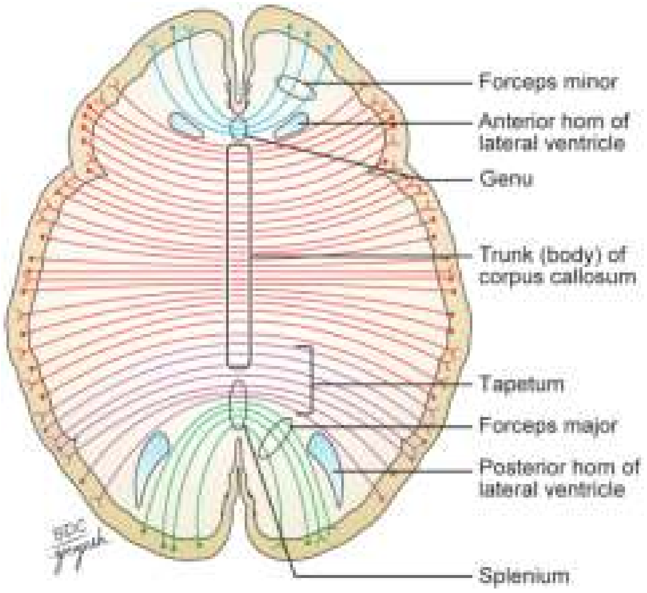

Forceps minor
Anterior horn of lateral ventricle
Genu
Trunk (body) of corpus callosum
Tapetum
Forceps major
Posterior horn of lateral ventricle
Splenium

Fig. 11.18: Fibres of corpus callosum

Forceps minor are fork-like commissural fibres of genu of corpus callosum that connect the either side of frontal lobes.

Tapetum: These are the fibres of corpus callosum that form the roof and lateral wall of the posterior horn of lateral ventricle and lateral wall of the inferior horn. These fibres do not intersect the fibres of corona radiata.

Forceps major are fork-like commissural fibres of corpus callosum that connect the occipital lobes.

Bulb of the posterior horn are the fibres of forceps major that bulge in the medial wall of the posterior horn of lateral ventricle.

CLINICAL NEUROANATOMY

Split-brain syndrome: In the congenital absence of corpus callosum, the two cerebral hemispheres work separate and patient behaves as he/she has two separate brains. This condition is called *split-brain syndrome*.

INTERNAL CAPSULE

The internal capsule is a large band of fibres, situated in the inferomedial part of each cerebral hemisphere.

Shape

In horizontal sections of the brain, it appears V-shaped with its concavity directed laterally. The concavity is occupied by the lentiform nucleus (Fig. 11.19 and Flowchart 11.8).

Relations

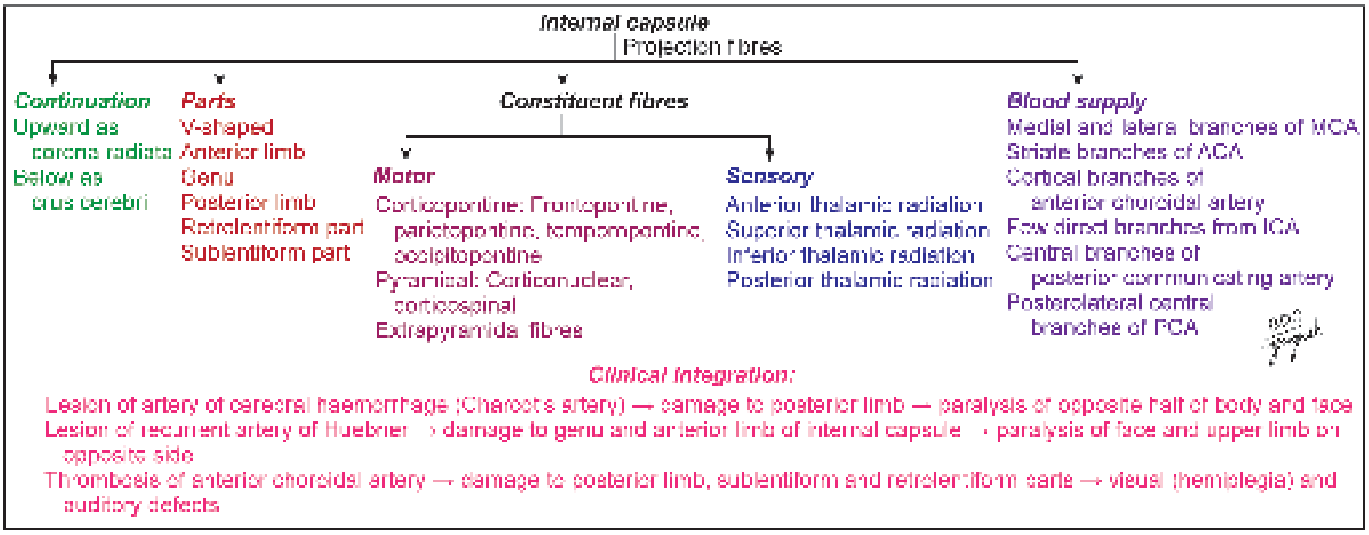
Medially: Head of caudate nucleus and thalamus.

Laterally: Lentiform nucleus.

Continuation

The internal capsule contains fibres going to and coming from the cerebral cortex. It can be compared to a narrow

Flowchart 11.8: Internal capsule



Internal capsule

Projection fibres

Continuation

Upward as corona radiata

Below as crus cerebri

Parts

V-shaped

Anterior limb

Genu

Posterior limb

Retrolentiform part

Sublentiform part

Constituent fibres

Motor

Corticopontine: Frontopontine, parietopontine, temporopontine, occipitopontine

Pyramidal: Corticonuclear, corticospinal

Extrapyramidal fibres

Sensory

Anterior thalamic radiation

Superior thalamic radiation

Inferior thalamic radiation

Posterior thalamic radiation

Blood supply

Medial and lateral branches of MCA

Striate branches of ACA

Cortical branches of anterior choroidal artery

Few direct branches from ICA

Central branches of posterior communicating artery

Posterolateral central branches of PCA

Clinical integration:

Lesion of artery of cerebral haemorrhage (Charcot's artery) — damage to posterior limb — paralysis of opposite half of body and face

Lesion of recurrent artery of Huebner → damage to genu and anterior limb of internal capsule → paralysis of face and upper limb on opposite side

Thrombosis of anterior choroidal artery → damage to posterior limb, sublentiform and retrolentiform parts → visual (hemiplegia) and auditory defects

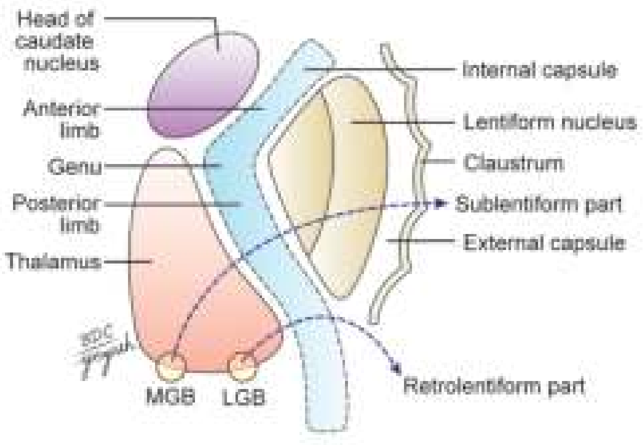


Fig. 11.19: Parts of internal capsule as seen in horizontal section

gate where the fibres are densely crowded. Small lesions of the capsule can give rise to widespread derangements of the body.

Corona radiata: The fibres of internal capsule fan out cranially and form corona radiata (radiating fibres like sunrays).

Crus cerebri: The fibre of internal capsule approximates inferiorly to form crus cerebri of midbrain.

Parts

The internal capsule is divided into the following parts:

a. *Anterior limb* lies between the head of the caudate nucleus and the lentiform nucleus.

b. *Genu* is the bend between the anterior and posterior limbs.

c. *Posterior limb* lies between the thalamus and the lentiform nucleus.

d. *Sublentiform part* lies below the lentiform nucleus. It can be seen in a coronal section, whereas the rest of the parts are seen in a horizontal section.

e. *Retrolentiform part* lies behind the lentiform nucleus.

Fibres of Internal Capsule (Table 11.5)

Motor Fibres

1. *Corticopontine fibres*
   - Frontopontine fibres from frontal lobe to pontine nuclei.
   - Parietopontine fibres from parietal lobe pontine nuclei.
   - Occipitopontine fibres from occipital lobe to pontine nuclei.
   - Temporopontine fibres from temporal lobe to pontine nuclei.
2. *Pyramidal fibres*
   - Corticonuclear fibres from cerebral cortex to contralateral motor nuclei of IIIrd, IVth, Vth to XIIth cranial nerves.
   - Corticospinal fibres from cerebral cortex to contralateral anterior horn cells of spinal cord.
3. *Extrapyramidal fibres* from cerebral cortex to subcortical nucleus such as red nucleus, substantia nigra, reticular nuclei, olivary nucleus, and so on.

Sensory Fibres (*Thalamocortical Fibres*)

The most of the sensory fibres received by thalamocortical fibres. They form thalamic radiation as follows:

1. *Anterior thalamic radiation* from anterior and dorsomedial nucleus of thalamus to the frontal lobe.
2. *Superior thalamic radiation* from ventral group of thalamic nuclei to sensory cortex of frontal and parietal lobes.
3. *Inferior thalamic radiation* from medial geniculate body to the primary auditory area of temporal lobe as *auditory radiation*.
4. *Posterior thalamic radiation* from lateral geniculate body to the primary visual area (area 17) as *optic radiation*.

Constituent fibres: The fibres of internal capsule are shown in Figs 11.20 and 11.21.

TABLE 11.5: Fibres in the internal capsule

Part	*Descending tracts*	*Ascending tracts*	*Arterial supply*
Anterior limb (Fig. 8.29)	Frontopontine fibres (a part of the corticopontocerebellar pathway)	Anterior thalamic radiation (fibres from anterior and medial nuclei of thalamus)	1. Recurrent branch of anterior cerebral 2. Direct branches from anterior cerebral
Genu	Corticonuclear fibres (a part of the pyramidal tract going to motor nuclei of cranial nerves and forming their supranuclear pathway)	Anterior part of the superior thalamic radiation (fibres from posterior ventral nucleus of thalamus)	1. Direct branches from internal carotid 2. Posterior communicating
Posterior limb	1. Corticospinal tract (pyramidal tract for the upper limb, trunk and lower limb) 2. Corticopontine fibres 3. Corticorubral fibres	1. Superior thalamic radiation 2. Fibres from globus pallidus to subthalamic nucleus	1. Lateral striate branches of middle cerebral 2. Medial striate branches of middle cerebral 3. Anterior choroidal
Sublentiform part	1. Parietopontine and temporopontine fibres 2. Fibres between temporal lobe and thalamus	1. Auditory radiation 2. Fibres connecting thalamus to temporal lobe	1. Branches of posterior cerebral 2. Anterior choroidal
Retrolentiform part	1. Parietopontine and occipitopontine fibres 2. Fibres from occipital cortex to superior colliculus and pretectal region	Posterior thalamic radiation made up of: 1. Mainly optic radiation 2. Partly fibres connecting thalamus to the parietal and occipital lobes	Branches of posterior cerebral

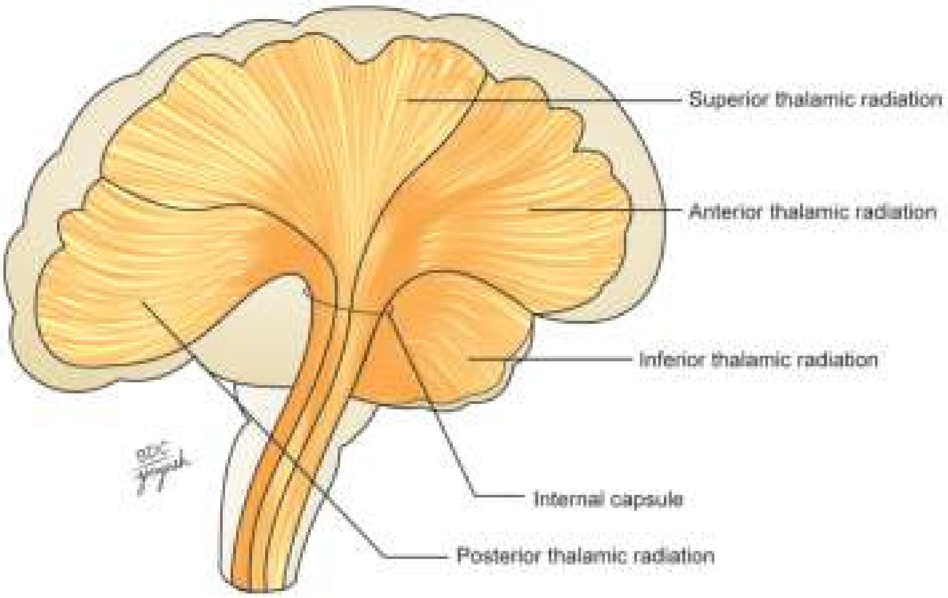

Superior thalamic radiation
Anterior thalamic radiation
Inferior thalamic radiation
Internal capsule
Posterior thalamic radiation

Fig. 11.20: Fibres of various parts of internal capsule

Blood Supply

The internal capsule gives passages to large number of fibres through a small zone. Hence, its vascular lesion affects large area of body. The internal capsule is supplied by the following arteries (Fig. 11.22):

1. Medial and lateral branches of middle cerebral artery.
2. Striate branches of anterior cerebral artery.
3. Cortical branches of anterior choroidal artery.
4. Few direct branches from internal carotid artery.
5. Central branches of the posterior communicating artery.
6. Posterolateral central branches of posterior cerebral artery.

Charcot's artery of cerebral haemorrhage is one of the lateral striate branches of the middle cerebral artery. It is a larger branch and more frequently ruptured.

Recurrent artery of Huebner is one of the striate branches of anterior cerebral artery which is large and takes the recurrent course.

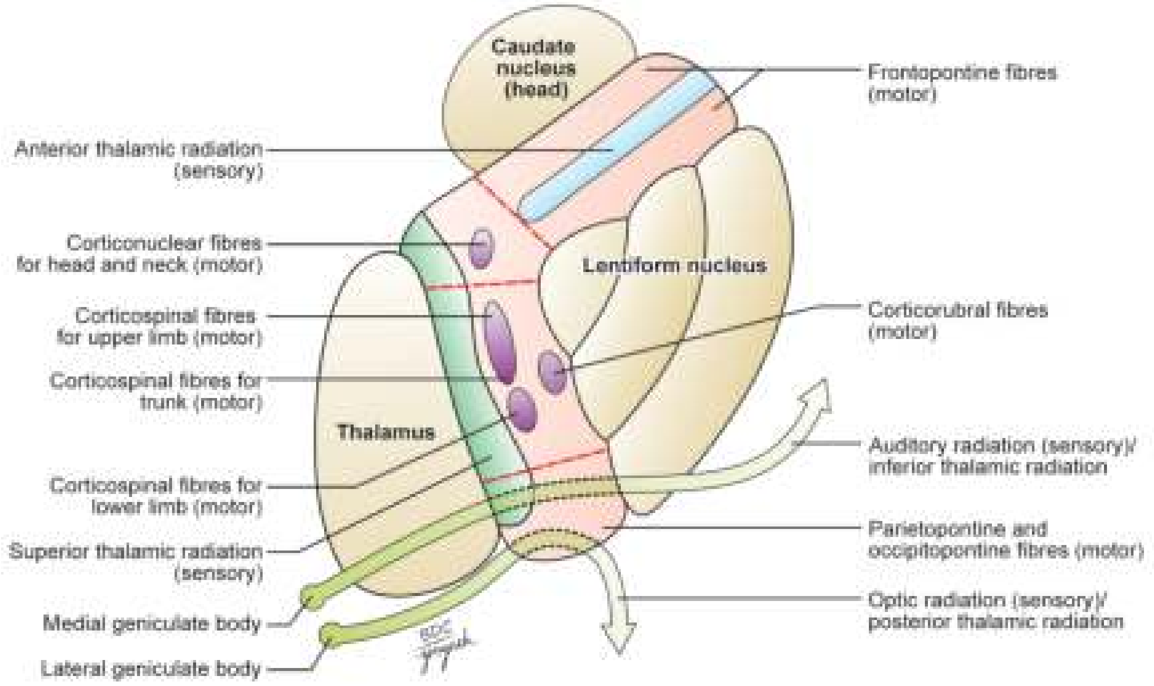

Caudate nucleus (head)
Frontopontine fibres (motor)
Anterior thalamic radiation (sensory)
Corticonuclear fibres for head and neck (motor)
Lentiform nucleus
Corticospinal fibres for upper limb (motor)
Corticorubral fibres (motor)
Corticospinal fibres for trunk (motor)
Thalamus
Auditory radiation (sensory)/ inferior thalamic radiation
Corticospinal fibres for lower limb (motor)
Parietopontine and occipitopontine fibres (motor)
Superior thalamic radiation (sensory)
Optic radiation (sensory)/ posterior thalamic radiation
Medial geniculate body
Lateral geniculate body
BDC

Fig. 11.21: Fibre components of internal capsule

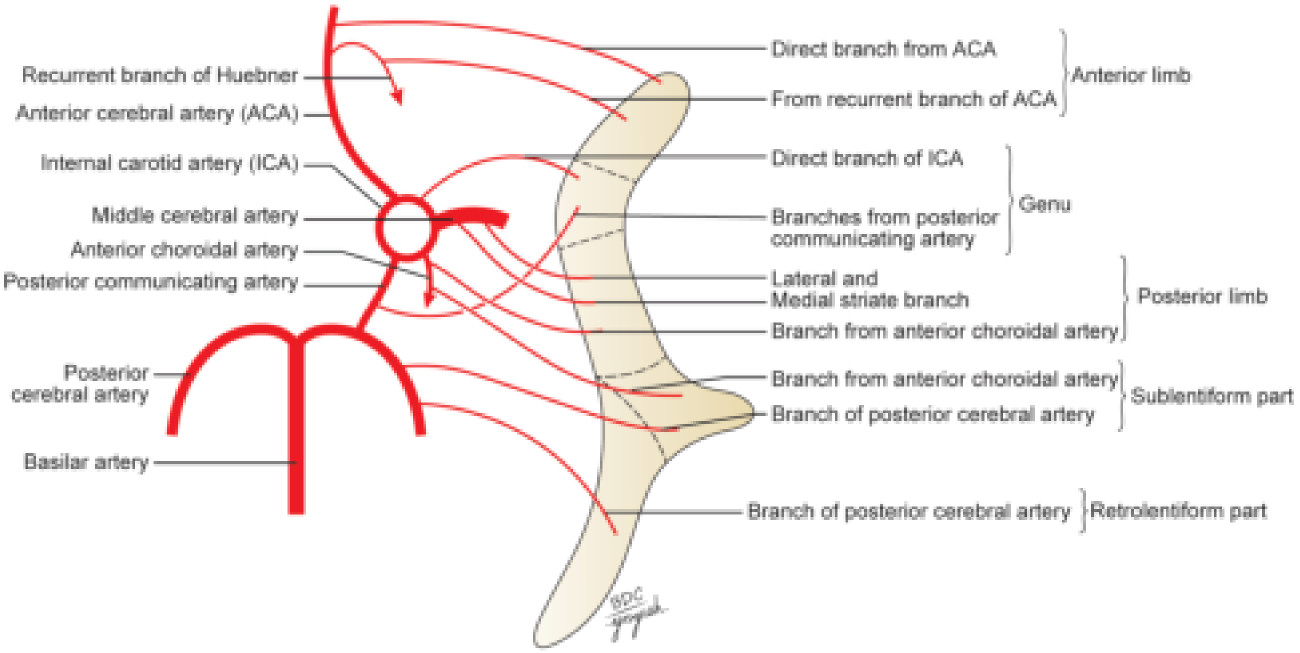

Recurrent branch of Huebner
Anterior cerebral artery (ACA)
Internal carotid artery (ICA)
Middle cerebral artery
Anterior choroidal artery
Posterior communicating artery
Posterior cerebral artery
Basilar artery
Direct branch from ACA
From recurrent branch of ACA
Anterior limb
Direct branch of ICA
Branches from posterior communicating artery
Genu
Lateral and Medial striate branch
Branch from anterior choroidal artery
Posterior limb
Branch from anterior choroidal artery
Branch of posterior cerebral artery
Sublentiform part
Branch of posterior cerebral artery
Retrolentiform part
BDC

Fig. 11.22: Arteries supplying the internal capsule

CLINICAL NEUROANATOMY

- ***Lesion of internal capsule:*** A vascular lesion of internal capsule is common. It involves rupture of vessels which results in haemorrhage or occlusion (necrosis). It occurs commonly in the medial and lateral branches of the middle cerebral artery. Effects lesion of internal capsule which results in upper motor neuron type of paralysis of the opposite half of body and face.
- ***Specific lesions***
  a. Lesion of artery of cerebral haemorrhage (Charcot's artery) → damage to the posterior limb → paralysis of opposite half of body and face (common cause of hemiplegia) (Fig. 11.23).
  b. Lesion of recurrent artery of Huebner → damage to genu and anterior limb of internal capsule → paralysis of face and upper limb on the opposite side.
  c. Thrombosis of anterior choroidal artery → damage to posterior limb, sublentiform and retrolentiform parts → visual (hemianopia) and auditory defects.

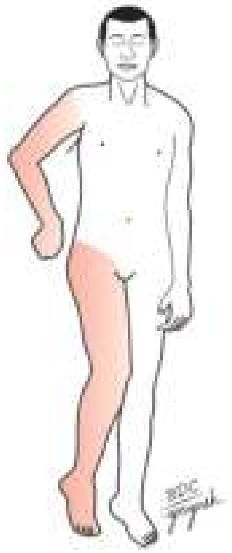


Fig. 11.23: Posture in right-sided hemiplegia

Video 4.8 **Cerebrum:** Superolateral surface, Inferior surface, Medial surface, Brodmann areas, White matter of brain.

Facts to Remember

- Cerebrum receives sensations from the opposite side of body. It controls the movements of the opposite side of body, a few structures are controlled by both sides.
- Body is represented upside down, only the face and area of vocalization are represented straight.
- Lateral sulcus has three limbs: Anterior horizontal, ascending, and posterior.
- Heschl's gyrus is anterior transverse temporal gyrus which is hidden by posterior ramus of lateral sulcus.
- Insula is the fifth lobe of the cerebral cortex.
- Paracentral lobule has the highest cortical centre of micturition.
- Areas 44 and 45 are Broca's area.
- Basal nuclei disorder produces parkinsonism.
- Corpus callosum is the largest bundle of commissural fibres.
- Internal capsule is the most typical example of projection fibres. Its posterior limb is supplied by lateral striate arteries. These are end arteries. Blockage or haemorrhage of these arteries causes upper motor neuron type of paralysis on the opposite side of the body.

BDC's Anatomy e-book

1. Types of sulci
2. Connections of motor area
3. Some functions of cerebrum
4. Human speech
5. Ageing changes in cerebrum
6. Further reading
7. Viva voce questions

Chapter

12

Lateral Ventricle and Limbic System

Competency:
AN63.1 Describe and demonstrate parts, boundaries and features of lateral ventricle.

LATERAL VENTRICLE

The lateral ventricles are two irregular cavities situated one in each cerebral hemisphere. Its capacity is about 7–10 ml (Figs 12.1a and b and 12.2 and Flowchart 12.1).

Communications

Each lateral ventricle communicates with the third ventricle through an interventricular foramen (foramen of Monro).

Contents

1. Cerebrospinal fluid
2. Choroid plexus.

PARTS OF LATERAL VENTRICLE

Each lateral ventricle consists of:

1. A central part
2. Three horns: Anterior, posterior and inferior (Figs 12.3a and b).

Central Part

This part of the lateral ventricle extends from the interventricular foramen in front to the splenium of the corpus callosum behind.

Boundaries

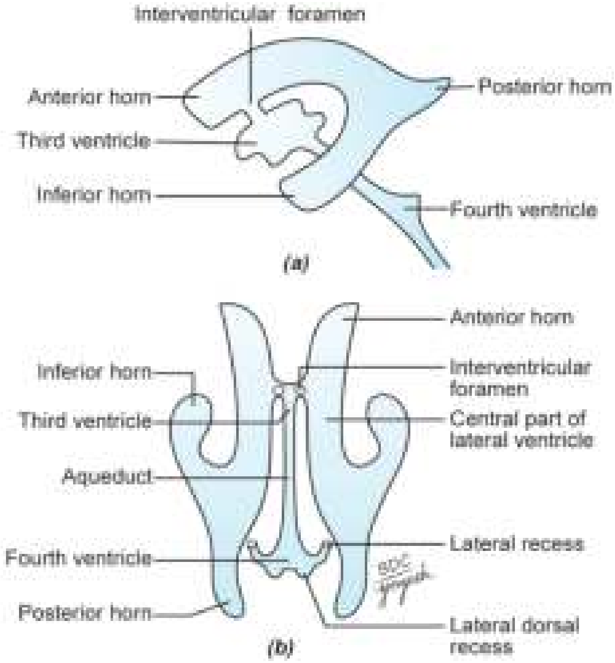
Roof: It is formed by the undersurface of the corpus callosum (Figs 12.4a and b).

Floor: It is formed (from lateral to medial side) by:

1. Body of caudate nucleus
2. Stria terminalis
3. Thalamostriate vein
4. Lateral portion of the upper surface of the thalamus
5. Choroid plexus
6. Upper surface of symmetric half of body of fornix.

Medial wall: It is formed by:

1. Septum pellucidum
2. Body of fornix.


Interventricular foramen
Anterior horn
Posterior horn
Third ventricle
Inferior horn
Fourth ventricle
(a)
Anterior horn
Inferior horn
Interventricular foramen
Third ventricle
Central part of lateral ventricle
Aqueduct
Lateral recess
Fourth ventricle
Posterior horn
Lateral dorsal recess
(b)

Figs 12.1a and b: Ventricles of the brain: (a) Lateral view and (b) superior view

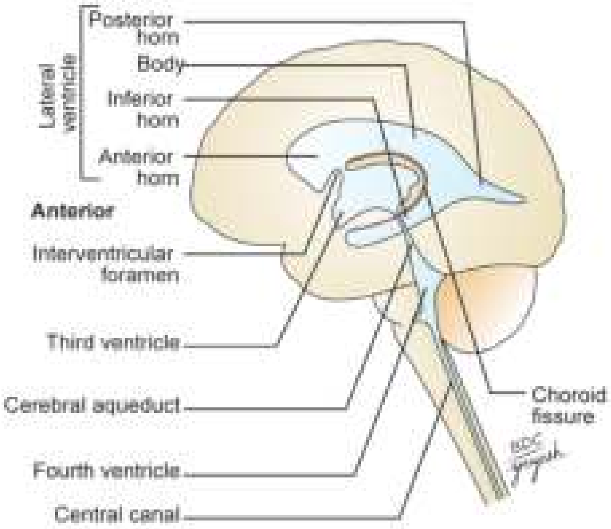
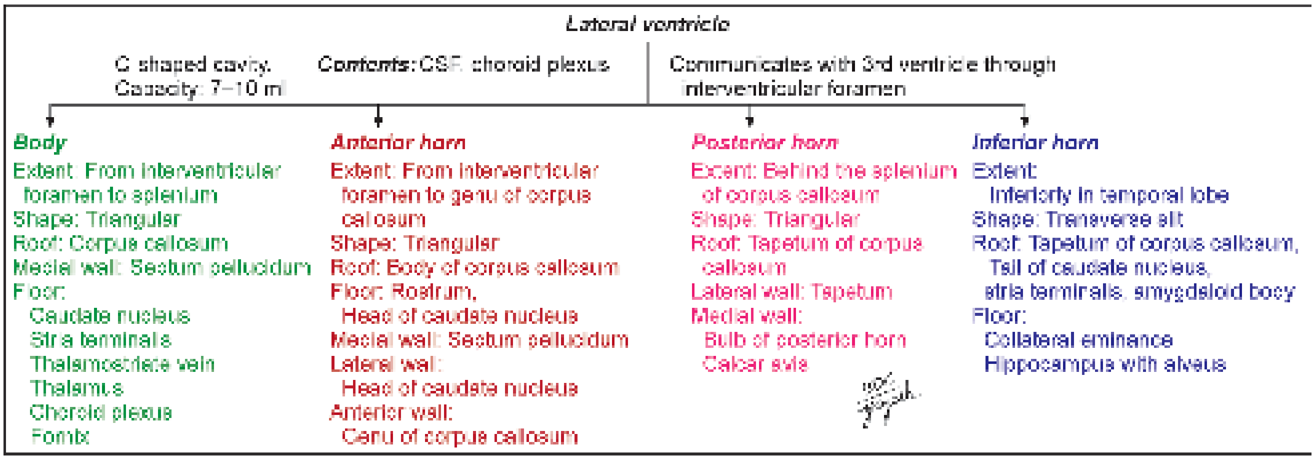

Lateral ventricle
Posterior horn
Body
Inferior horn
Anterior horn
Anterior
Interventricular foramen
Third ventricle
Cerebral aqueduct
Fourth ventricle
Central canal
Choroid fissure

Fig. 12.2: Ventricle seen from the lateral surface

Flowchart 12.1: Lateral ventricle



Lateral ventricle

C shaped cavity.
Capacity: 7–10 ml

Contents: CSF, choroid plexus

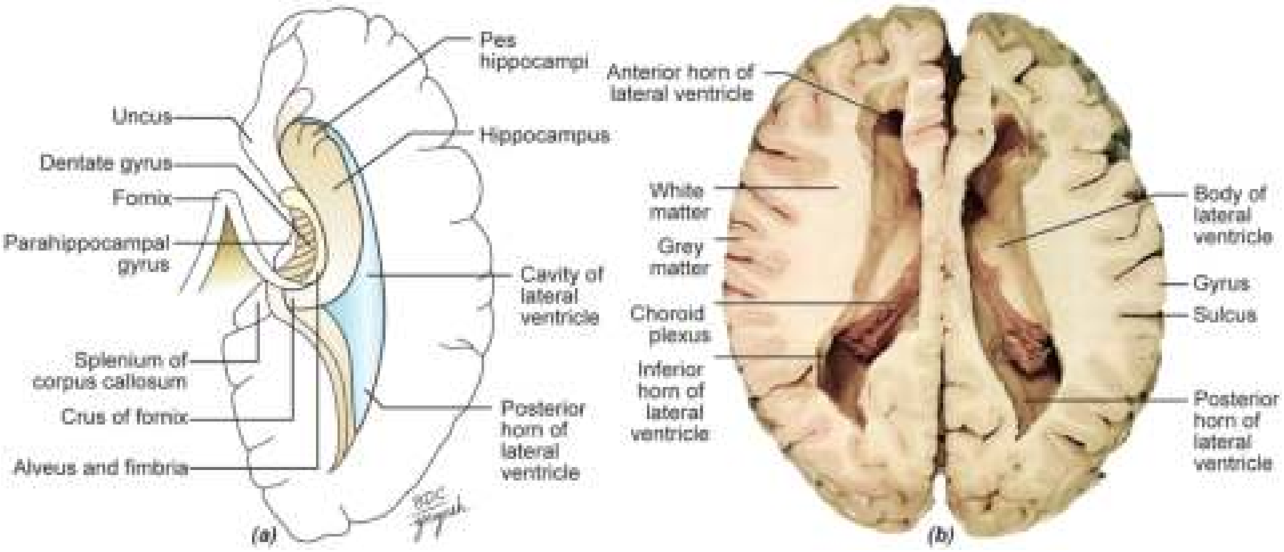
Communicates with 3rd ventricle through interventricular foramen

Body
- Extent: From interventricular foramen to splenium
- Shape: Triangular
- Roof: Corpus callosum
- Medial wall: Septum pellucidum
- Floor:
  - Caudate nucleus
  - Stria terminalis
  - Thalamostriate vein
  - Thalamus
  - Choroid plexus
  - Fornix

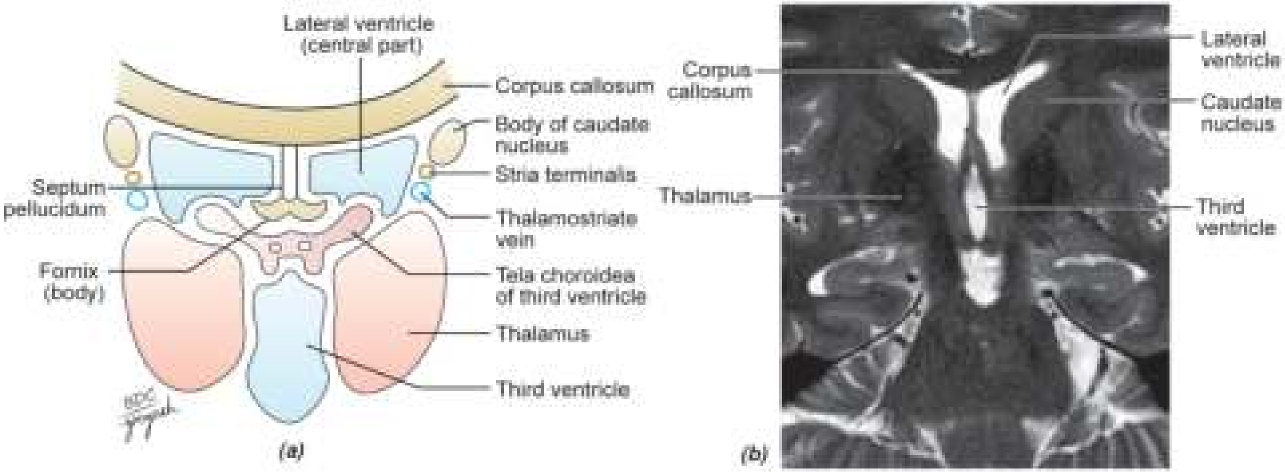
Anterior horn
- Extent: From interventricular foramen to genu of corpus callosum
- Shape: Triangular
- Roof: Body of corpus callosum
- Floor: Rostrum,
  - Head of caudate nucleus
- Medial wall: Septum pellucidum
- Lateral wall:
  - Head of caudate nucleus
- Anterior wall:
  - Genu of corpus callosum

Posterior horn
- Extent: Behind the splenium of corpus callosum
- Shape: Triangular
- Roof: Tapetum of corpus callosum
- Lateral wall: Tapetum
- Medial wall:
  - Bulb of posterior horn
  - Calcar avis

Inferior horn
- Extent:
  - Inferiorly in temporal lobe
- Shape: Transverse slit
- Roof: Tapetum of corpus callosum, Tail of caudate nucleus, stria terminalis, amygdaloid body
- Floor:
  - Collateral eminence
  - Hippocampus with alveus


Pes hippocampi
Uncus
Dentate gyrus
Fornix
Parahippocampal gyrus
Hippocampus
Cavity of lateral ventricle
Splenium of corpus callosum
Crus of fornix
Alveus and fimbria
Posterior horn of lateral ventricle
(a)
Anterior horn of lateral ventricle
White matter
Grey matter
Choroid plexus
Inferior horn of lateral ventricle
Body of lateral ventricle
Gyrus
Sulcus
Posterior horn of lateral ventricle
(b)

Figs 12.3a and b: Cavity of lateral ventricle including its anterior horn, body, inferior and posterior horns


Lateral ventricle (central part)
Corpus callosum
Body of caudate nucleus
Stria terminalis
Septum pellucidum
Thalamostriate vein
Fornix (body)
Tela choroidea of third ventricle
Thalamus
Third ventricle
(a)
Corpus callosum
Thalamus
Lateral ventricle
Caudate nucleus
Third ventricle
(b)

Figs 12.4a and b: (a) Boundaries of third ventricle and central part of lateral ventricle (coronal section) and (b) MRI showing third ventricle and part of lateral ventricle

Choroid Fissure

The line along which the choroid plexus invaginates into the lateral ventricle is called the choroid fissure. It is a C-shaped slit in the medial wall of the cerebral hemisphere. It starts at the interventricular foramen (above and in front) and passes around the thalamus and cerebral peduncle to the uncus (in the temporal lobe). Thus, it is present only in relation to the central part and inferior horn of the lateral ventricle. Its convex margin is bounded by the fornix (body and crus), the fimbria and the hippocampus, and the concave margin is bounded by the thalamus (superior and posterior surfaces), the tail of the caudate nucleus and the stria terminalis. At the fissure, the pia mater and ependyma come into contact with each other and both are invaginated into the ventricle by the choroid plexus.

In the central part of lateral ventricle, the choroid fissure is a narrow gap between the edge of the fornix and the upper surface of the thalamus. The gap is invaginated by the choroid plexus.

Anterior Horn

This is the part of the lateral ventricle which lies in front of the interventricular foramen and extends into the frontal lobe. It is directed forwards, laterally and downwards, and is triangular on cross-section (Figs 12.5a and b).

Boundaries

Anterior: Posterior surface of genu and rostrum of the corpus callosum.

Roof: Anterior part of the trunk of the corpus callosum.

Floor

1. Head of the caudate nucleus.
2. Upper surface of the rostrum of the corpus callosum.

Medial

1. Septum pellucidum
2. Column of fornix.

Posterior Horn

This is the part of the lateral ventricle which lies behind the splenium of the corpus callosum and extends into the occipital lobe. It is directed backwards and medially (Fig. 12.6).

Boundaries

Floor and medial wall

1. Bulb of the posterior horn raised by the forceps major.
2. Calcar avis raised by the anterior part of the calcarine sulcus.

Roof and lateral wall: Tapetum fibres of optic radiation.

Inferior Horn

This is the largest horn of the lateral ventricle. It begins at the junction of the central part with the posterior horn of the lateral ventricle; and extends into the temporal lobe (Fig. 12.7).

Boundaries

Roof and lateral wall

1. Chiefly the tapetum
2. Tail of caudate nucleus
3. Stria terminalis
4. Amygdaloid body.

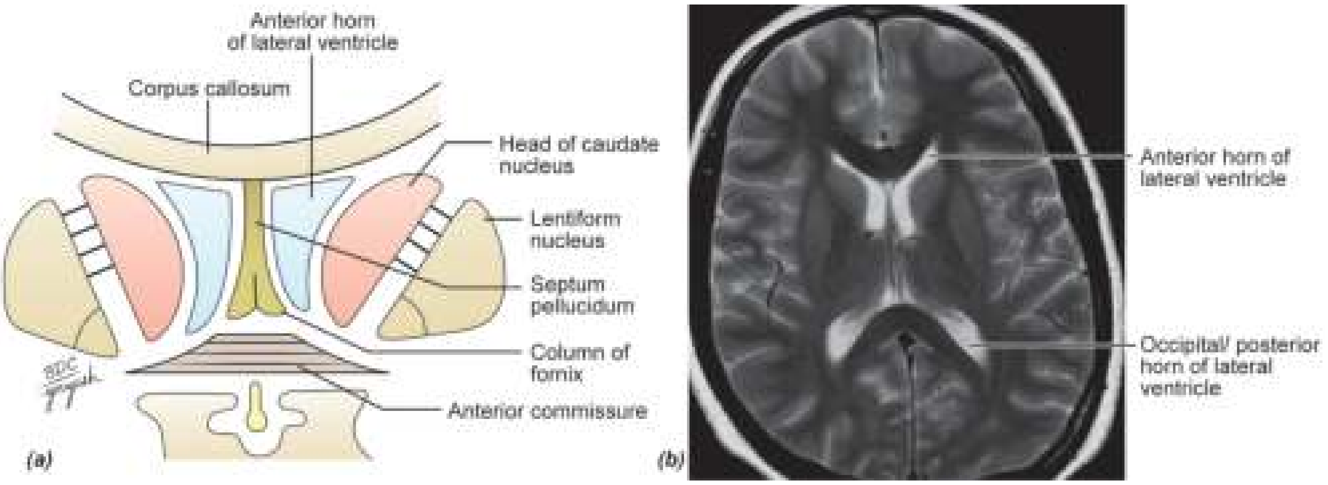
Floor

1. Collateral eminence raised by the collateral sulcus.
2. Hippocampus, medially.

In the inferior horn, the line of ependymal invagination by the choroid plexus (i.e. the choroid fissure) lies between the stria terminalis and the fimbria.

CLINICAL NEUROANATOMY

For visualisation of lateral ventricle, computerised axial tomography (CT), scanning and magnetic resonance imaging (MRI) are useful.


Anterior horn of lateral ventricle
Corpus callosum
Head of caudate nucleus
Lentiform nucleus
Septum pellucidum
Column of fornix
Anterior commissure
(a)
(b)
Anterior horn of lateral ventricle
Occipital/ posterior horn of lateral ventricle

Figs 12.5a and b: (a) Boundaries of anterior horn of lateral ventricle (coronal section) and (b) MRI of anterior and occipital horns of lateral ventricles

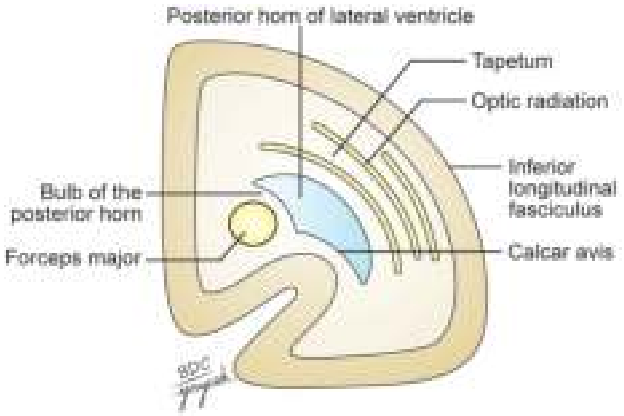

Posterior horn of lateral ventricle
Tapetum
Optic radiation
Inferior longitudinal fasciculus
Calcar avis
Bulb of the posterior horn
Forceps major

Fig. 12.6: Boundaries of posterior horn of lateral ventricle (coronal section)

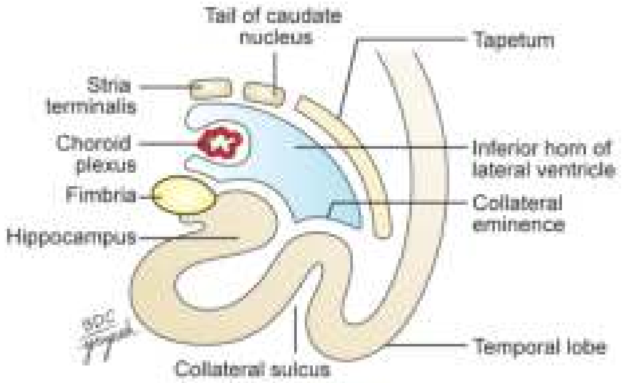

Tail of caudate nucleus
Tapetum
Stria terminalis
Choroid plexus
Fimbria
Hippocampus
Inferior horn of lateral ventricle
Collateral eminence
Temporal lobe
Collateral sulcus

Fig. 12.7: Boundaries of inferior horn of lateral ventricle (coronal section)

DISSECTION

Take the right hemisphere and put the tip of the knife at the interventricular foramen. Give a vertical incision through the fornix, septum pellucidum, body of corpus callosum, the medial surface of the hemisphere till the superomedial border (Fig. 12.8a).

Turn the brain so that superolateral surface points towards you. Continue the previous incision on this surface for 2 cm. Carry the incision posteriorly and then curve it downwards till the end of the posterior ramus of the lateral sulcus (Fig. 12.8b).

Expose the insula by depressing the temporal lobe. Cut through the medial part of the gyri situated on the superior surface of the temporal lobe till the stem of the lateral sulcus (Fig. 12.8c).

Now try to separate the frontal lobe from the temporal lobe, and open up the stem of the lateral sulcus. Put the knife in the anterior part of stem of the lateral sulcus and extend the incision medially to the inferior part of stem of the lateral sulcus. Keep on opening the cut while making it and identify the choroid plexus entering the inferior horn of the lateral ventricle from its medial side.

Now brain is easily separable into an upper frontal part and a lower occipitotemporal part. Lift the fornix from the thalamus, separating the fornix from the choroid plexus. Identify the choroidal branches of the posterior cerebral artery.

Identify structures in all horns of lateral ventricle with the help of the two parts, i.e. frontal and occipitotemporal parts of the cerebral hemisphere.

Expose the anterior column of fornix by scraping the ependyma of anterior part of third ventricle. Trace the anterior column of fornix till the mammillary body. Trace another bundle, the mammillothalamic tract till the anterior nucleus of the thalamus.

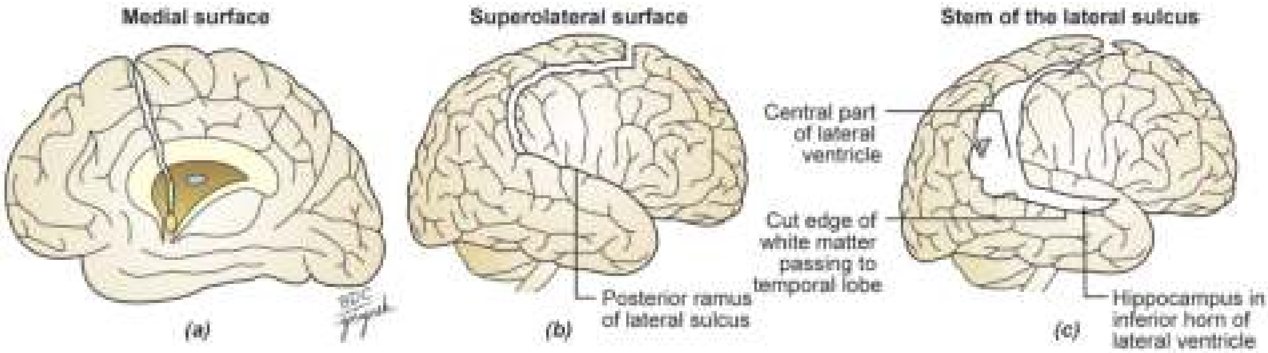
Competency:

AN62.4 Enumerate parts and major connections of basal ganglia and limbic lobe.

LIMBIC SYSTEM

Limbic system (*limbus* = ring, *limbic* = border) is a part of cortical and subcortical structures that performs the primary maintenance of the organism, that is, food and sex.

Rhinencephalon (*smell brain*) is the previous name of limbic system. It is associated with sense of smell and smaller in size in humans.


Medial surface
Superolateral surface
Stem of the lateral sulcus
Central part of lateral ventricle
Cut edge of white matter passing to temporal lobe
Posterior ramus of lateral sulcus
Hippocampus in inferior horn of lateral ventricle
(a)
(b)
(c)

Figs 12.8a to c: (a) The first incision to be made in the dissection to expose the lateral ventricle, (b) the second part of the incision to be made in the dissection to expose the lateral ventricle, and (c) the third part of the incision to complete the exposure of the lateral ventricle

The ***limbic cortex*** is allocortex, hence consists of three neuronal layers. The transition zone (3 to 6 neuronal layers) is called *juxta-allocortex* that lies between allocortex and neocortex. The neocortex consists of six neuronal layers.

Functions of Limbic System

1. Emotional reactions
2. Integration of olfactory, visceral, and somatic impulses
3. Learning and retention of recent memory.

Emotional reactions, that are essential for maintenance of self and species, include:

1. Procuring, storing, and eating food
2. Sex
3. Rearing of young
4. Other emotions: Fear, rage, defence reactions, production of salivation and nausea on perception of smell
5. Visceral responses based on emotions.

Thus, limbic system is called *visceral brain*.

Components of Limbic System

The limbic system consists of many cortical and subcortical areas (Fig. 12.10, Flowchart 12.2). Hypothalamus is major control headquarter.

Cortical Area

1. *Limbic lobe*: It consists of paraterminal (subcallosal) gyrus, cingulate gyrus, isthmus, parahippocampal gyrus, uncus, collateral and rhinal sulci (Fig. 12.9). (*Note*: Currently use of the term 'limbic lobe' is decreased).
2. *Hippocampal formation*: It consists of hippocampus, dentate gyrus, gyrus fasciolaris, and indusium griseum (Fig. 12.10).

Subcortical Structures

1. Amygdaloid body
2. Septal nuclei
3. Olfactory areas
4. Hypothalamus – main headquarter of limbic system
5. Anterior nucleus of thalamus.

Fibres of Limbic System

They include:

1. Fornix
2. Mammillothalamic tract
3. Stria medullaris thalami
4. Stria terminalis
5. Medial forebrain bundle
6. Anterior commissure

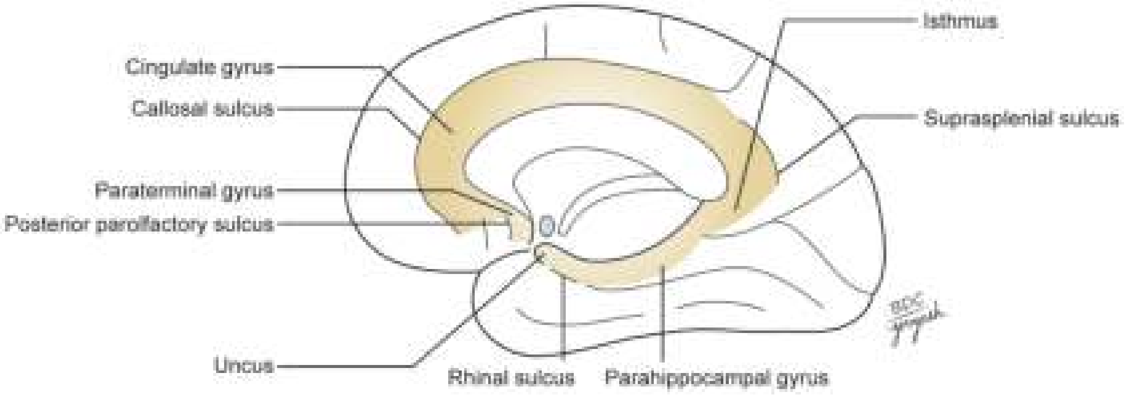

Isthmus
Cingulate gyrus
Callosal sulcus
Suprasplenial sulcus
Paraterminal gyrus
Posterior parolfactory sulcus
Uncus
Rhinal sulcus
Parahippocampal gyrus

Fig. 12.9: Limbic lobe (medial surface of the right cerebral hemisphere)

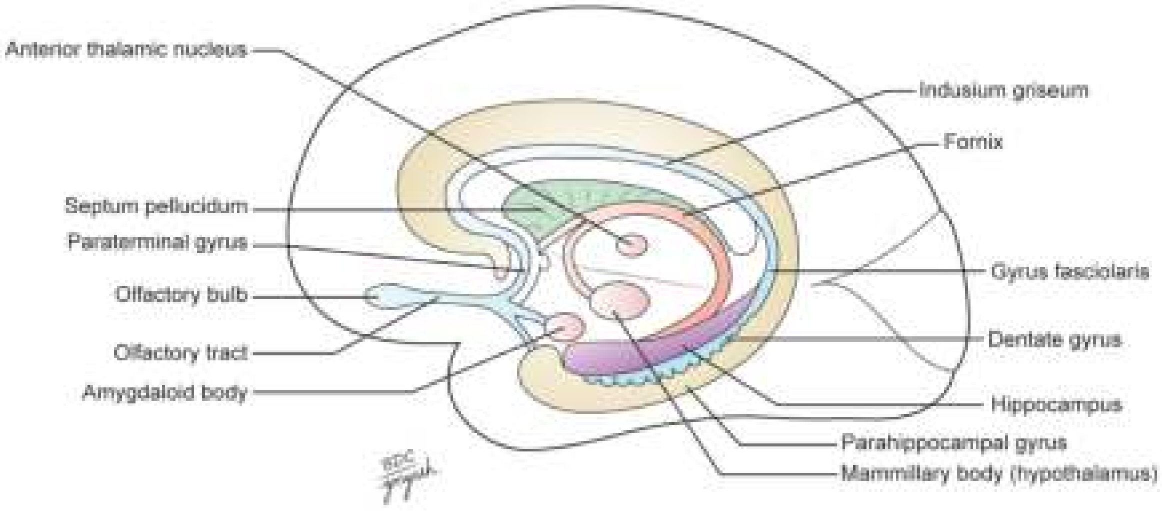
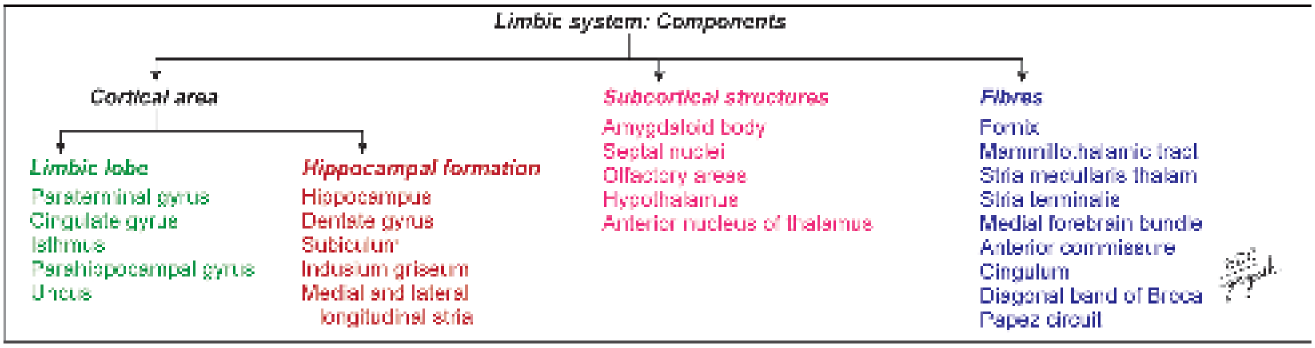

Anterior thalamic nucleus
Indusium griseum
Fornix
Septum pellucidum
Paraterminal gyrus
Gyrus fasciolaris
Olfactory bulb
Dentate gyrus
Olfactory tract
Amygdaloid body
Hippocampus
Parahippocampal gyrus
Mammillary body (hypothalamus)

Fig. 12.10: Components of hippocampal formation

Flowchart 12.2: Limbic system: Components


Limbic system: Components
Cortical area
Limbic lobe
Paraterminal gyrus
Cingulate gyrus
Isthmus
Parahippocampal gyrus
Uncus
Hippocampal formation
Hippocampus
Dentate gyrus
Subiculum
Indusium griseum
Medial and lateral longitudinal stria
Subcortical structures
Amygdaloid body
Septal nuclei
Olfactory areas
Hypothalamus
Anterior nucleus of thalamus
Fibres
Fornix
Mammillothalamic tract
Stria medullaris thalami
Stria terminalis
Medial forebrain bundle
Anterior commissure
Cingulum
Diagonal band of Broca
Papez circuit

7. Cingulum
8. Diagonal band of Broca
9. Papez circuit.

Areas Concerned with Sense of Smell

The limbic system performs its function based on the sense of smell and other sensory stimuli (Fig. 12.11).

1. The *olfactory nerve* receives sensory input from olfactory mucosa. The *olfactory bulb* is a small oval structure that is situated above the cribriform plate of ethmoid. The *olfactory tract* is a narrow band of white fibres that passes backwards from the olfactory bulb to the anterior perforated substance.
2. ***Olfactory trigone*** is flattened posterior end of olfactory tract. It divides into medial, lateral, and intermediate olfactory stria.
   a. *Medial olfactory stria* continues in the paraterminal gyrus which lies in front of lamina terminalis.
   b. *Lateral olfactory stria* runs laterally and continues into the *limen insulae*. It turns medially to form *gyrus semilunaris* (periamygdaloid area).
   c. *Intermediate olfactory stria* is occasionally present. It ends as *olfactory tubercle* in the *anterior perforated substance*.
   d. *Medial and lateral olfactory gyri* are the thin layers of grey matter that cover the medial and lateral olfactory stria.

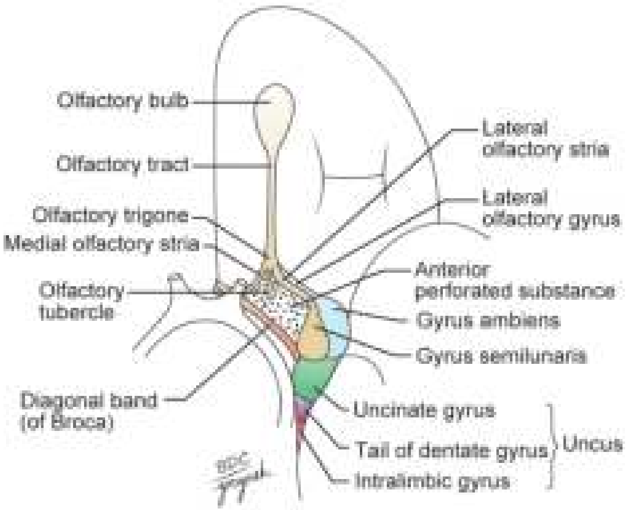

Olfactory bulb
Olfactory tract
Olfactory trigone
Medial olfactory stria
Olfactory tubercle
Diagonal band (of Broca)
Lateral olfactory stria
Lateral olfactory gyrus
Anterior perforated substance
Gyrus ambiens
Gyrus semilunaris
Uncinate gyrus
Tail of dentate gyrus
Intralimbic gyrus
Uncus

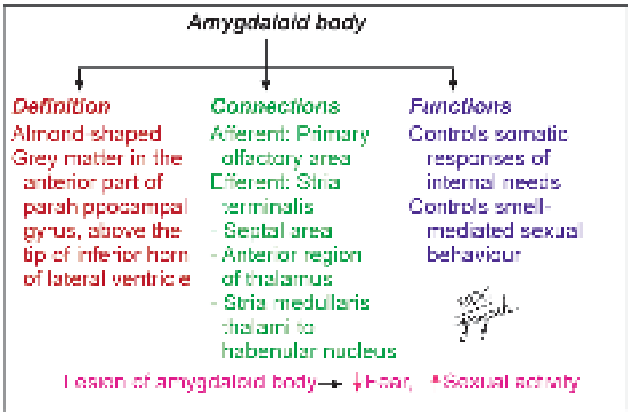
Fig. 12.11: Areas concerned with sense of smell

3. The ***anterior perforated substance*** is a small, depressed area of grey matter. It is perforated by central branches of the anterior and middle cerebral arteries.
4. ***Limen insulae*** is a small ridge connecting the anterior perforated substance with the apex of insula.
5. ***Parahippocampal gyrus*** lies on the tentorial surface of cerebral hemisphere. It lies medial to the collateral sulcus. Posteriorly, it is continuous with the *isthmus* and *lingual gyrus*. It has centre for taste and smell. ***Uncus*** is the anterior 2.5 cm of the parahippocampal gyrus. It is hook-like. *Rhinal notch* separates the uncus from the temporal pole. Uncus lies just behind the anterior perforated substance.
6. ***Primary olfactory area*** is responsible for reception and perception of smell. It includes lateral olfactory gyrus, gyrus ambiens, gyrus semilunaris, limen insulae, uncus and dorsomedial part of amygdaloid body. The ***secondary olfactory gyrus*** or *entorhinal area* performs the olfactory association. It includes the anterior part of parahippocampal gyrus. It is called area 28. The ***isthmus*** connects the cingulate gyrus with the parahippocampal gyrus. It lies behind the splenium of corpus callosum.
7. ***Septal area and septal nuclei*** is considered as pleasure zone. It consists of:
   a. ***Paraterminal gyrus*** is a narrow strip of cortex that lies along the anterior surface of lamina terminalis.
   b. ***Paraolfactory (subcallosal) gyrus*** is a narrow lamina on the medial surface cerebral hemisphere in front of lamina terminalis. It is continuous around the genu of corpus callosum with indusium griseum (*supracallosal gyrus*).
   c. ***Paraolfactory area (subcallosal area)*** is a small triangular area on the medial surface of cerebral hemisphere. It lies anterior to the subcallosal gyrus. Inferiorly, it is continuous with *olfactory trigone*.

Amygdaloid Body

It is almond-shaped mass of grey matter that lies in the anterior part of parahippocampal gyrus. It lies above the tip of the inferior horn of lateral ventricle, beneath the lentiform nucleus (Flowchart 12.3). Posteriorly, it is continuous with tail of caudate nucleus and stria terminalis.

Flowchart 12.3: Amygdaloid body


Amygdaloid body
Definition
Almond-shaped
Grey matter in the anterior part of parahippocampal gyrus, above the tip of inferior horn of lateral ventricle
Connections
Afferent: Primary olfactory area
Efferent: Stria terminalis
- Septal area
- Anterior region of thalamus
- Stria medullaris thalami to habenular nucleus
Functions
Controls somatic responses of internal needs
Controls smell-mediated sexual behaviour
Lesion of amygdaloid body → ↓Fear, ↑Sexual activity

Connections

Afferent: From primary olfactory area.

Efferent: Stria terminalis – the efferent fibres of amygdaloid body form stria terminalis. It takes a C-shaped course along with caudate nucleus.

Termination: Stria terminalis ends in septal area and anterior region of thalamus. *Stria medullaris thalami* – these are some fibres of stria terminalis that run backwards and end in the habenular nucleus.

Functions

1. Controls the somatic responses of internal needs
2. Controls the smell-mediated sexual behaviour.

Hippocampal Formation

The hippocampal formation is a part of limbic system. It consists of (Plate 12.1, Figs 12.12 and 12.13):

1. ***Hippocampus*** is C-shaped grey matter (resembles seahorse or rams' horn). Hence, called *Ammon's horn* (mythology – Ammon was Egyptian deity with ram's head). It is located in the floor of inferior horn of lateral ventricle. ***Pes hippocampus*** is an anterior end of hippocampus with 2–3 digit-like ridges (similar to animals' paw, *pes* = foot). The ***alveus*** is thin layer of white matter that covers the ventricular surface of hippocampus. These are efferent fibres of hippocampus. The efferent fibres of hippocampus from alveus posteriorly these fibres converge to form ***fimbria of hippocampus***. It is a flattened band of white matter. It lies superior to the dentate gyrus. The fibres of fimbria of hippocampus continue posteriorly as ***crus of fornix***.
2. ***Dentate gyrus*** is a narrow crenated, toothed strip of grey matter. It lies on the upper surface of parahippocampal gyrus. Posteriorly, it is continuous with gyrus fasciolaris through indusium griseum. The dentate gyrus runs medially across the inferior surface of uncus. Here, it forms the ***tail of dentate gyrus***.
3. ***Subiculum*** lies between the hippocampus proper and entorhinal area at the inferomedial part of the cerebral hemisphere. It is a transition zone (3 to 6 neuronal layers) and hence called juxta-allocortex.
4. ***Indusium griseum*** (*supracallosal gyrus*) is a thin layer of grey matter that covers the superior surface of

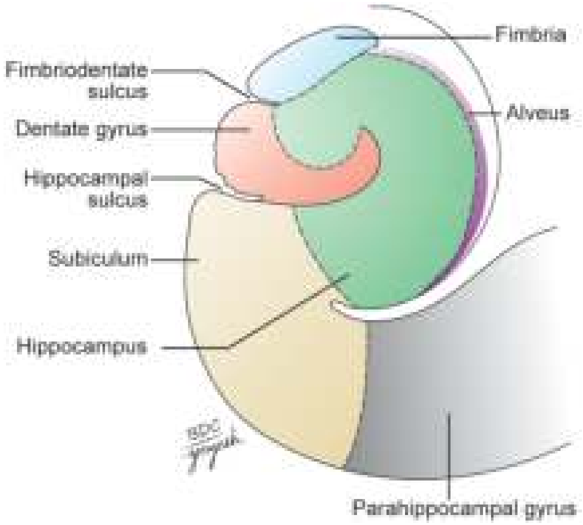

Fimbria
Fimbriodentate sulcus
Alveus
Dentate gyrus
Hippocampal sulcus
Subiculum
Hippocampus
Parahippocampal gyrus

Fig. 12.12: Hippocampal formation (coronal section of right cerebral hemisphere, posterior view)

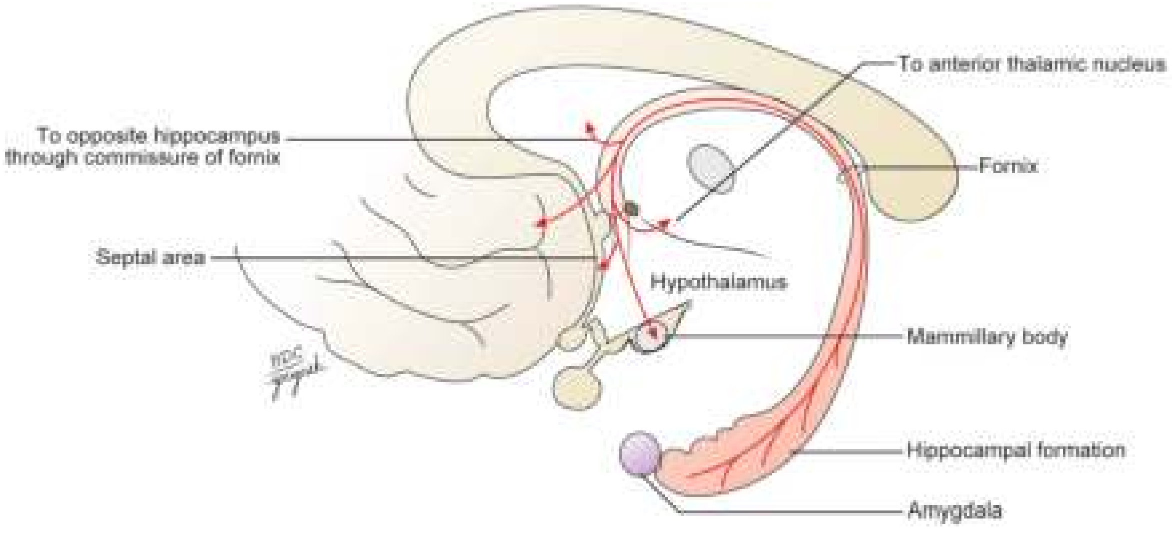
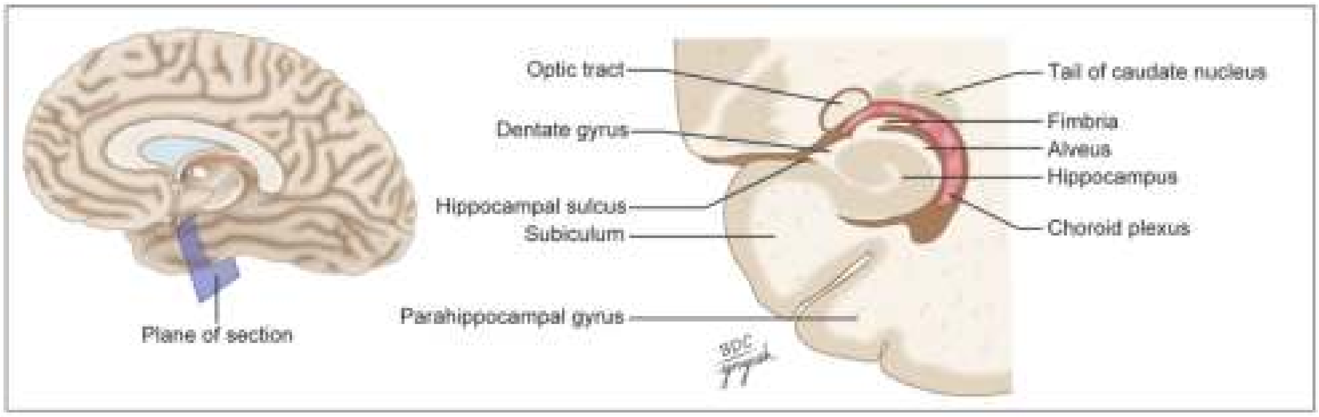

To anterior thalamic nucleus
To opposite hippocampus through commissure of fornix
Fornix
Septal area
Hypothalamus
Mammillary body
Hippocampal formation
Amygdala

Fig. 12.13: Connection of hippocampus

Plate 12.1: Hippocampal formation (coronal section of right cerebral hemisphere)


Optic tract
Dentate gyrus
Hippocampal sulcus
Subiculum
Parahippocampal gyrus
Plane of section
Tail of caudate nucleus
Fimbria
Alveus
Hippocampus
Choroid plexus

corpus callosum. Anteriorly, it is continuous with paraterminal gyrus and posteriorly with gyrus fasciolaris.

5. ***Medial and lateral longitudinal stria*** are two thin longitudinal strands of white fibres on each side. They are embedded in indusium griseum.

Functions

1. Physiologically, a part of limbic system.
2. Controls endocrine and visceral functions and emotional status
3. Recent memory.

Connection of hippocampus

- *Afferent*: From entorhinal area
- *Efferent*: Through fornix → to opposite hippocampus, septal area, anterior hypothalamic regions, mammillary body.

Fornix

The fornix is an arched bundle of projection fibres from hippocampus to the mammillary body (Fig. 12.14 and Flowchart 12.4).

Formation

The fornix made-up of efferent fibres of hippocampus. Axon of pyramidal cells of hippocampus → alveus (thin sheet of white matter covering ventricular surface of hippocampus) → fimbria (flat band) → crus of fornix.

1. *Crus of fornix*: Curves upwards behind the thalamus.
2. *Body of fornix*: Both the crura (right and left) converge in the midline to form the body of fornix. It lies above the roof of third ventricle and below the splenium and body of corpus callosum.
3. *Commissure of fornix*: Few fibres of crura decussate just posterior to the body of fornix as commissure of fornix (hippocampal commissure).
4. *Anterior column of fornix*: Anteriorly, the body of fornix divides downwards to the anterior columns. Each anterior column curves downwards to the anterior commissure. It extends through the hypothalamus and ends in the mammillary body. Its few fibres terminate into septal areas.

Functions: The fornix is efferent tract of hippocampus.

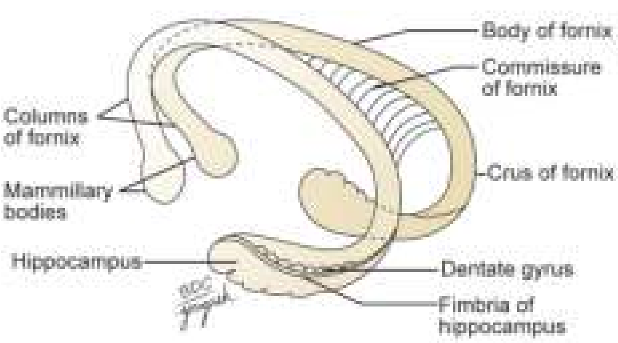
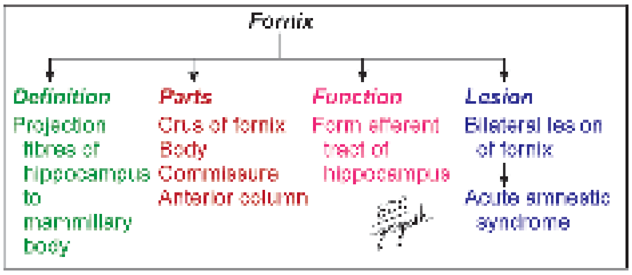

Body of fornix
Commissure of fornix
Columns of fornix
Mammillary bodies
Crus of fornix
Hippocampus
Dentate gyrus
Fimbria of hippocampus

Fig. 12.14: Fornix (left lateral view with posterior oblique tilt)

Flowchart 12.4: Fornix


Fornix
Definition
Projection fibres of hippocampus to mammillary body
Parts
Crus of fornix
Body
Commissure
Anterior column
Function
Form efferent tract of hippocampus
Lesion
Bilateral lesion of fornix
Acute amnestic syndrome

Papez Circuit

It is an intraneuronal communication of limbic system that forms the basis for emotional experiences [*James Wenceslas Papez, American neuroanatomist, 1883–1958*] (Flowchart 12.5).

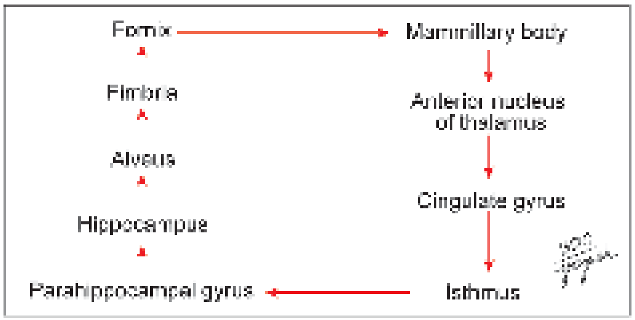
Components

1. Hippocampal formation
2. Fornix
3. Mammillary body
4. Anterior nucleus of thalamus
5. Cingulate gyrus
6. Entorhinal cortex.

Functions

The papez circuit plays an import role in emotion and consolidation of memory [short-term → long-term memory].

Flowchart 12.5: Papez circuit



CLINICAL NEUROANATOMY

- Hippocampus can be regarded as the cortical centre for autonomic reflexes. Hippocampal-amygdala complex is related to the memory of recent events. Lesions of this complex are associated with a loss of memory for recent events only. Patient is unable to commit any new facts to memory and does not remember recent events. The lesion of hippocampus results in loss of recent memory and psychomotor epilepsy.
- A bilateral damage to the fornix causes inability in consolidation of short-term memory into long-term memory. This is called ***acute amnestic syndrome***.
- Bilateral damage to amygdaloid body → reduction in fear and increase in sexual activity. A lesion that affects the uncus and amygdaloid body may cause, '***uncinate fits***' characterised by an imaginary disagreeable odour, by movements of lips and tongue, and often by a 'dreamy state'.
- Destruction of olfactory nerves results in loss of the sense of smell (anosmia).
- A tumour, usually a meningioma, in the floor of anterior cranial fossa may interfere with the sense of smell because of pressure on olfactory bulb and the olfactory tract. It is necessary to test each nostril separately because the olfactory loss is likely to be unilateral.

VIDEO

Video 4.9 **Ventricles of Brain**

Facts to Remember

- Lateral ventricle is the largest ventricle of the brain.
- The right and left lateral ventricles communicate with the single third ventricle through the interventricular foramen.
- Limbic system comprises connections of fornix and Papez circuits. These are mostly present on the flat medial surface of cerebral hemisphere.

BDC's Anatomy *e*-book

1. Further reading
2. Viva voce questions

Chapter

13

Some Neural Pathways and Reticular Formation

SOME NEURAL PATHWAYS

The descending tracts controls the activity of the body through the pyramidal and extrapyramidal tracts (For details, Chapter 5).

The ascending tracts carry the sensory input to the central nervous system. They carry the following sensations:

1. Pain and temperature sensation
2. Fine touch and conscious proprioception
3. Unconscious proprioception.

The special sensory pathways carry the olfactory, light, auditory, and taste sensations.

Pyramidal Tracts

For the pyramidal tract, see the descriptions given in Chapter 5. This is a descending tract, extending from the cerebral cortex to various motor nuclei of the cranial nerves as corticobulbar tracts and spinal nerves as corticospinal tracts. It constitutes the upper motor neuron in the motor pathway from the cortex to voluntary muscles. Corticonuclear fibres reach the nuclei of cranial nerves (Fig. 13.1).

Before termination, all fibres of the pyramidal tract cross to opposite side. They terminate, mostly through an interneuron, in the motor nuclei of cranial nerves and in relation to the anterior horn cells of the spinal cord. The fibres which terminate in the motor nuclei of the cranial nerves collectively form the corticonuclear tract.

CLINICAL NEUROANATOMY

Effects of lesion of the pyramidal tract: Lesions above the level of decussation cause contralateral paralysis, while lesions below the decussation cause ipsilateral paralysis. It is an upper motor neuron type of paralysis which is characterised by the following:

a. Loss of the power of voluntary movements.
b. Clasp-knife type of rigidity (hypertonia).
c. Tendon reflexes are exaggerated.
d. Superficial reflexes are lost.
e. Babinski's sign is positive.
f. Reaction of degeneration is absent.

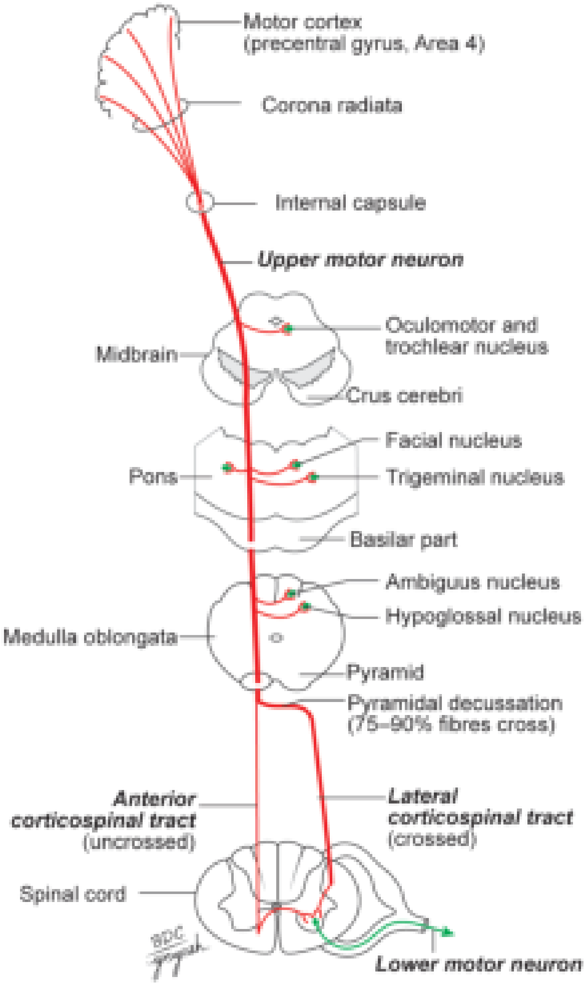

Motor cortex
(precentral gyrus, Area 4)
Corona radiata
Internal capsule
Upper motor neuron
Oculomotor and
trochlear nucleus
Midbrain
Crus cerebri
Facial nucleus
Pons
Trigeminal nucleus
Basilar part
Ambiguus nucleus
Hypoglossal nucleus
Medulla oblongata
Pyramid
Pyramidal decussation
(75–90% fibres cross)
Anterior
corticospinal tract
(uncrossed)
Lateral
corticospinal tract
(crossed)
Spinal cord
Lower motor neuron

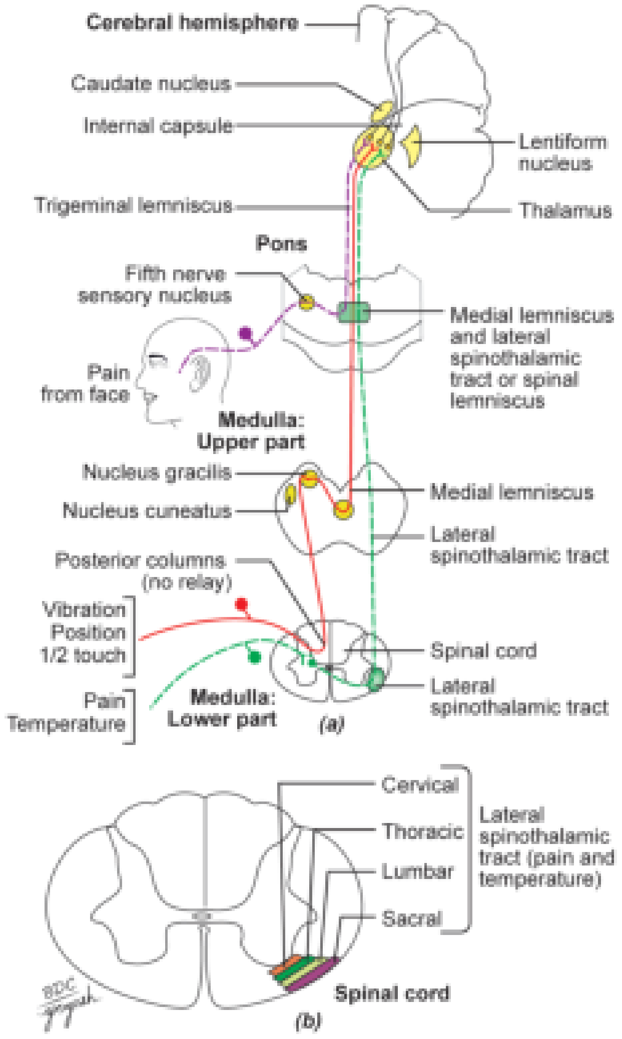
Fig. 13.1: Pathway of pyramidal fibres

Pathway of Pain and Temperature

These sensations are carried from the opposite half of the body and face by the lateral spinothalamic tract and the trigeminal nerve respectively. For details *see* Chapter 5. It consists of three order neurons (Figs 13.2a and b).

For the lateral spinothalamic tract:

1. First order neurons are located in the dorsal root ganglia.
2. Second order neurons are located in the grey matter of the spinal cord. Their axons form the lateral spino-


Cerebral hemisphere
Caudate nucleus
Internal capsule
Lentiform nucleus
Trigeminal lemniscus
Thalamus
Pons
Fifth nerve sensory nucleus
Medial lemniscus and lateral spinothalamic tract or spinal lemniscus
Pain from face
Medulla: Upper part
Nucleus gracilis
Nucleus cuneatus
Medial lemniscus
Lateral spinothalamic tract
Posterior columns (no relay)
Vibration
Position
1/2 touch
Spinal cord
Pain
Temperature
Medulla: Lower part
Lateral spinothalamic tract
(a)
Cervical
Thoracic
Lumbar
Sacral
Lateral spinothalamic tract (pain and temperature)
Spinal cord
(b)

Figs 13.2a and b: Pathway of: (a) Posterior column and (b) pain and temperature impulses

thalamic tract and later the spinal lemniscus in the brainstem.

3. Third order neuron lies in the ventral posterolateral nucleus of the thalamus. Fibres arising in this nucleus pass through the internal capsule and the corona radiata to reach the somatosensory areas 3, 1, 2 of cerebral cortex.

For face, head and neck: The first order neurons lie in the trigeminal ganglion. They form spinal tract of trigeminal nerve in the brainstem. The second order neurons lie in the spinal nucleus of trigeminal nerve. Their crossed axons form trigeminothalamic tract. The third order neurons lie in the ventral posteromedial nucleus of the thalamus. Fibres arising in this nucleus pass through the internal capsule and the corona radiata to reach the somatosensory areas 3, 1, 2 of cerebral cortex.

Pathway of Fine Touch, Proprioceptive (Kinaesthetic) Impulses—Position, Movement, Vibration

These sensations are carried from the opposite half of the body and face by the fasciculus gracilis and the fasciculus cuneatus and the trigeminal nerve respectively. For details *see* Chapter 5. It consists of three order neurons.

For the lateral spinothalamic tract:

1. First order neuron is located in the dorsal root ganglia. Their axons ascend in the spinal cord as the fasciculus gracilis and the fasciculus cuneatus in the dorsal white column.
2. Second order neuron is located in the nucleus gracilis or nucleus cuneatus in the medulla oblongata. Their axons cross to form internal arcuate fibres which further ascend as the medial lemniscus in the brainstem.
3. Third order neuron lies in the ventral posterolateral nucleus of the thalamus. Fibres arising in this nucleus pass through the internal capsule and the corona radiata to reach the somatosensory areas 3, 1, 2 of cerebral cortex.

For face, head and neck: The first order neurons lie in the trigeminal ganglion. The second order neurons lie in the mesencephalic nucleus of trigeminal nerve in the midbrain. Their crossed axons reach thalamus. The third order neurons lie in the ventral posteromedial nucleus of the thalamus. Fibres arising in this nucleus pass through the internal capsule and the corona radiata to reach the somatosensory areas 3, 1, 2 of cerebral cortex.

Pathway of Crude Touch and Pressure

These sensations are carried from the opposite half of the body and face by the anterior spinothalamic tract and the trigeminal nerve respectively. For details *see* Chapter 5.

For the anterior spinothalamic tract:

1. First order neurons are located in the dorsal root ganglia.
2. Second order neurons are located in the grey matter of the spinal cord. Their axons form the anterior spinothalamic tract and later the spinal lemniscus in the brainstem.
3. Remaining pathway is similar to lateral spinothalamic tract.

For face, head and neck: The first order neurons lie in the trigeminal ganglion. They form spinal tract of trigeminal nerve in the brainstem. The second order neurons lie in the spinal nucleus of trigeminal nerve. Their crossed axons form trigeminothalamic tract. The third order neurons lie in the ventral posteromedial nucleus of the thalamus. Fibres arising in this nucleus pass through the internal capsule and the corona radiata to reach the somatosensory areas 3, 1, 2 of cerebral cortex.

Pathway of Unconscious Proprioceptive Impulses

These impulses end in the cerebellum.

1. The first neuron has been described above.
2. The *second neuron* fibres are represented by three tracts—the posterior and anterior spinocerebellar tracts (from the lower limb and trunk) and the cuneocerebellar tract (posterior external arcuate fibres) from the upper limb.

The *posterior spinocerebellar tract* contains ipsilateral fibres arising in dorsal (thoracic) nucleus of the spinal cord. It enters the ipsilateral cerebellar hemisphere through the inferior cerebellar peduncle.

The *anterior spinocerebellar tract* is made up mainly of crossed fibres arising from the spinal grey matter (posterior grey column). The fibres ascend to the upper part of pons and then turn down into the superior cerebellar peduncle to reach the cerebellum of same side.

The *cuneocerebellar tract (posterior external arcuate fibres)* is functionally similar to the posterior spinocerebellar tract. It arises from the accessory (external) cuneate nucleus which receives afferents from the fasciculus cuneatus. The tract enters the ipsilateral cerebellar hemisphere through the inferior cerebellar peduncle.

Taste Pathway

1. The taste from anterior two-thirds of tongue except from vallate papillae is carried by chorda tympani branch of facial nerve till the geniculate ganglion. The central processes go to the tractus solitarius in the medulla (Fig. 13.3).
2. Taste from posterior one-third of tongue including the vallate papillae is carried by cranial nerve IX till the inferior ganglion. The central processes also reach the tractus solitarius.
3. Taste from the posterior most part of tongue and epiglottis travels through vagus nerve till the inferior ganglion of vagus. These central processes also reach tractus solitarius.
4. After a relay in tractus solitarius, the solitariothalamic tract is formed which becomes a part of trigeminal lemniscus and reaches the ventroposteromedial nucleus of thalamus of opposite side. Another relay here takes the fibres to lowest part of postcentral gyrus, which is the area for taste.

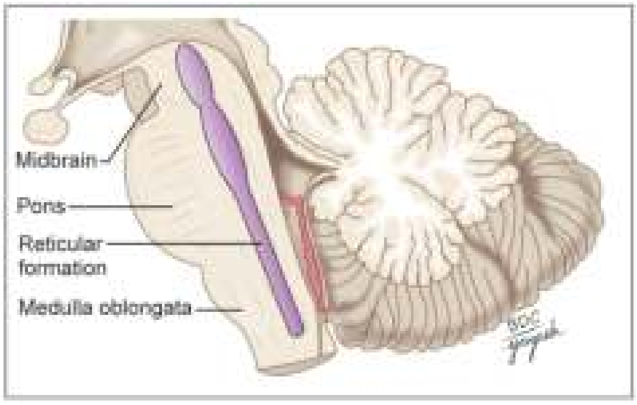
Visual Pathway and Auditory Pathways

These are described in Chapter 6.

RETICULAR FORMATION

The reticular formation is a diffuse (ill-defined) mass of grey matter with intermingled nerve fibres. It extends throughout the brainstem (Plate 13.1 and Fig. 13.4).

Plate 13.1: Location of reticular formation in the brainstem


Midbrain
Pons
Reticular formation
Medulla oblongata

Functions

1. *Arousal*: Reticular formation maintains the state of consciousness (ascending reticular activating system).
2. Controls *autonomic reflex centers* of brainstem – regulation of respiration, heart rate and blood pressure.
3. Regulation of endocrine, visceral and emotional responses.
4. Influences motor activity through extrapyramidal connections.
5. Modulates sensory inputs, especially pain.

Reticular Nuclei

The neurons of reticular formation form bilaterally the following three longitudinal nuclei as follows:

1. *Raphe nuclei*
2. *Magnocellular or medial column*
3. *Parvocellular or lateral column*
4. The paramedian nuclei are also present that lie in pons and medulla.

Raphe Nuclei

They lie in the paramedian position. They produce serotonin. They include:

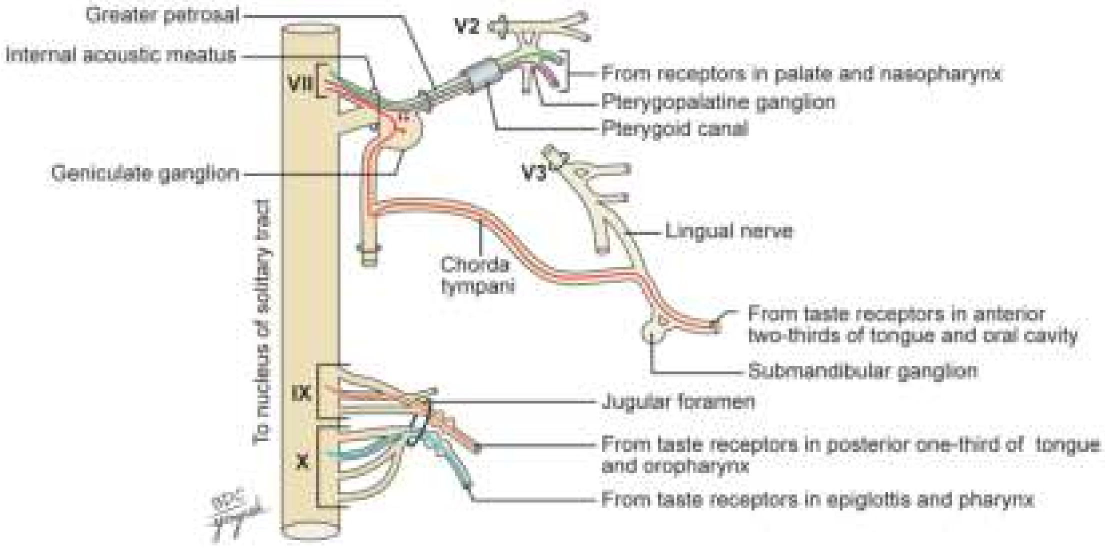

Greater petrosal
Internal acoustic meatus
VII
V2
From receptors in palate and nasopharynx
Pterygopalatine ganglion
Pterygoid canal
Geniculate ganglion
V3
Lingual nerve
Chorda tympani
To nucleus of solitary tract
From taste receptors in anterior two-thirds of tongue and oral cavity
Submandibular ganglion
IX
Jugular foramen
X
From taste receptors in posterior one-third of tongue and oropharynx
From taste receptors in epiglottis and pharynx

Fig. 13.3: Taste pathway

1. *Dorsal raphe nucleus* and *dorsal tegmental nucleus* in the midbrain. They form pain controlling pathway.
2. Superior central nucleus, nucleus raphe pontis, and nucleus raphe magnus in pons.
3. *Nucleus raphe pallidus and nucleus raphe obscurus* in the medulla oblongata. They modulate pain sensation.

Medial Group of Nuclei

They influence other neurons through polysynaptic pathway. They include:

1. Pontine nuclei – oral and caudal
2. Medullary nuclei – gigantocellular reticular nucleus, and ventral reticular nucleus.

Lateral Group of Nuclei

They receive information of ascending tracts and give efferent to medial group of nuclei.

They include:

1. In midbrain: Cuneiform nucleus, parabrachial nucleus, and pedunculopontine nucleus.
2. In pons: Parabrachial nucleus, pedunculopontine nucleus, and parvocellular nucleus.
3. In medulla: Parvocellular nucleus.

Connections

Reticular formation receives almost all sensory and motor information and influences most of the body responses based on this input. They receive afferents from spinoreticular fibres, visual inputs by tectoreticular fibres, auditory inputs by tectoreticular fibres, olfactory inputs by descending fibres from limbic system, fibres from cerebrum, corpus striatum, cerebral cortex and contralateral reticular and cranial nerve nuclei (Fig. 13.5).

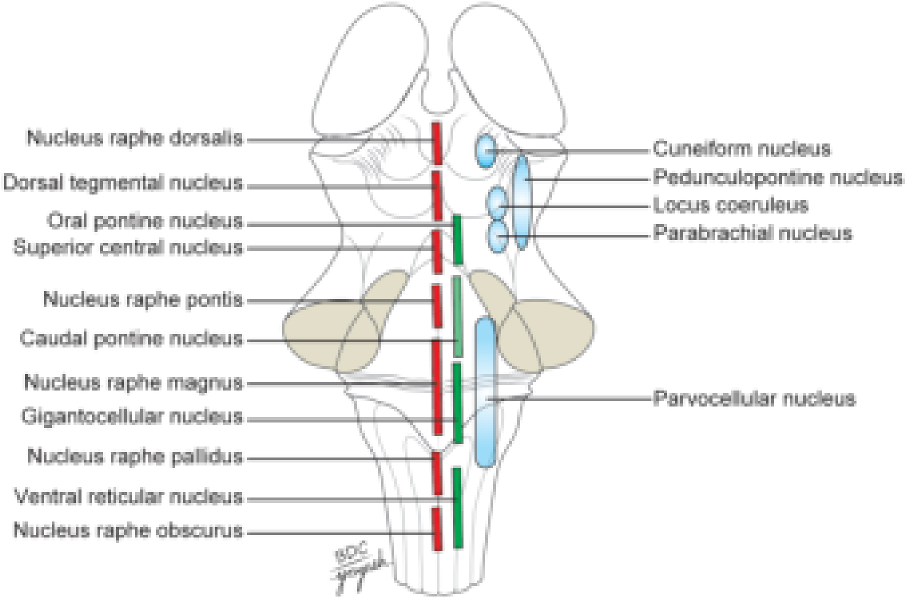

Nucleus raphe dorsalis
Dorsal tegmental nucleus
Oral pontine nucleus
Superior central nucleus
Nucleus raphe pontis
Caudal pontine nucleus
Nucleus raphe magnus
Gigantocellular nucleus
Nucleus raphe pallidus
Ventral reticular nucleus
Nucleus raphe obscurus
Cuneiform nucleus
Pedunculopontine nucleus
Locus coeruleus
Parabrachial nucleus
Parvocellular nucleus

Fig. 13.4: Schematic diagram to show the reticular nuclei in the brainstem (posterior view of brainstem) *Note*: Paramedian group of nuclei are not shown

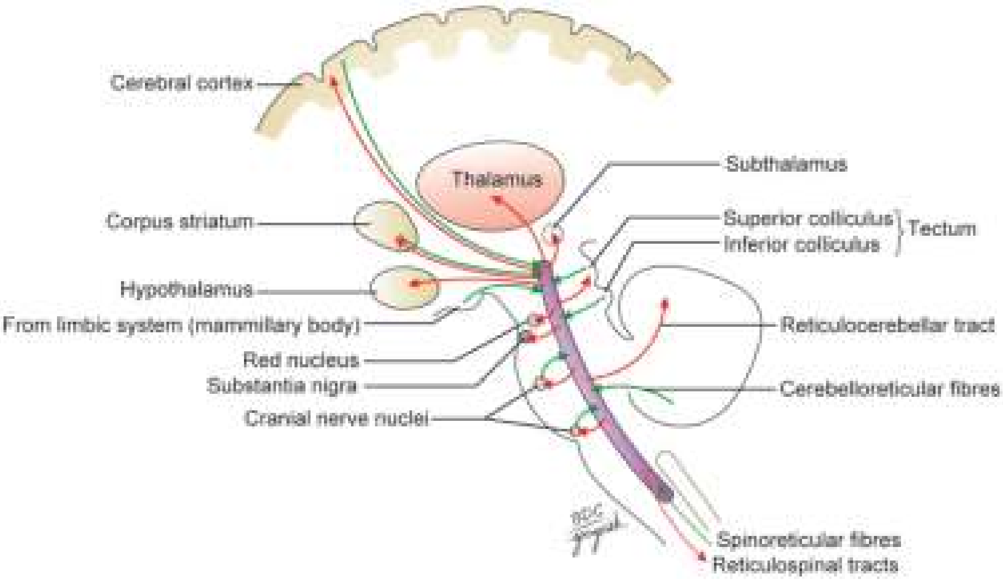

Cerebral cortex
Thalamus
Subthalamus
Corpus striatum
Superior colliculus
Inferior colliculus
Tectum
Hypothalamus
From limbic system (mammillary body)
Reticulocerebellar tract
Red nucleus
Substantia nigra
Cerebelloreticular fibres
Cranial nerve nuclei
Spinoreticular fibres
Reticulospinal tracts

Fig. 13.5: Major connections of reticular formation

These nuclei give rise to the reticulospinal tracts, reticulobulbar tract, reticulocerebellar tract. They also give rise to efferent fibres to the red nucleus, substantia nigra and tectum of midbrain, subthalamus, thalamus, hypothalamus, corpus striatum, and the cerebral cortex (Fig. 13.5).

Ascending Reticular Activating System (ARAS)

It is also called reticular activating system (RAS). It is responsible for wakefulness and alertness.

The ascending fibres of all sensory tracts of spinal cord and cranial nerve give collaterals to the reticular formation. The efferent fibres from this reticular formation project to the cerebral cortex through thalamus. It stimulates wide area of cerebral cortex, and the individual becomes alert.

CLINICAL NEUROANATOMY

- *Coma*: Bilateral lesion of RAS causes coma (state of unconscious). In coma patients, the powerful sensory stimuli fail to cause arousal.
- *Sleep*: Decreased activity of RAS induces sleep.
- *Drug-effect on RAS*: General anaesthetics and tranquilizing drugs cause suppression of RAS.
- Severe damage to RAS may cause loss of consciousness, coma and even death.

Facts to Remember

- Corticonuclear fibres give fibres to cranial nerve nuclei.
- The corticonuclear fibres of one side of cortex reach VII nerve nucleus of both sides which supply the muscles of upper half of face on both sides. It also gives fibres to nucleus of VII and supply to lower half of facial muscles only on the contralateral side.
- Unconscious impulses reach ipsilateral cerebellum, while conscious impulses reach the contralateral cerebrum.
- Anterior spinothalamic tract carrying crude touch and pressure joins the medial lemniscus during its upward journey through the brainstem. Thus, medial lemniscus carries conscious proprioceptive sensations, i.e. movement, vibration and position including whole touch and pressure to the thalamus.
- Nucleus of tractus solitarius receives impulses of taste through chorda tympani, branch of VII from most of anterior two-thirds of tongue; through glossopharyngeal from circumvallate papillae and posterior one-third of tongue. It also receives impulses from posteriormost part of tongue and vallecula via internal laryngeal branch of vagus nerve.

BDC's Anatomy e-book

1. Functions of reticular system
2. Action of drugs on reticular system
3. Viva voce questions

Chapter

14

Blood Supply of Brain

The nervous tissue is too delicate to bear anoxia beyond three minutes. The blood supply to nervous tissue per unit tissue is maximum in the body. It shows the importance of the grey matter. The blood supply may be erratic due to haemorrhage, thrombosis or embolism of the arteries supplying the nervous tissue. Further the arteries are 'end arteries' once these reach the deeper level.

ARTERIES OF BRAIN

Two vertebral and two internal carotid arteries carry the total arterial supply to the brain (Figs 14.1 and 14.2).

VERTEBRAL ARTERIES

The vertebral artery on each side is a branch of first part of subclavian artery. Its course is divided into four parts:

- 1st part lies from its origin to the foramen transversarium of 6th cervical vertebra.
- 2nd part courses through foramen transversaria of 6th to 1st cervical vertebrae (Plate 14.1).
- 3rd part lies on the posterior arch of atlas vertebra in the suboccipital triangle.
- 4th part of the vertebral artery enters the cranium through foramen magnum under the free margin of posterior atlanto-occipital membrane.

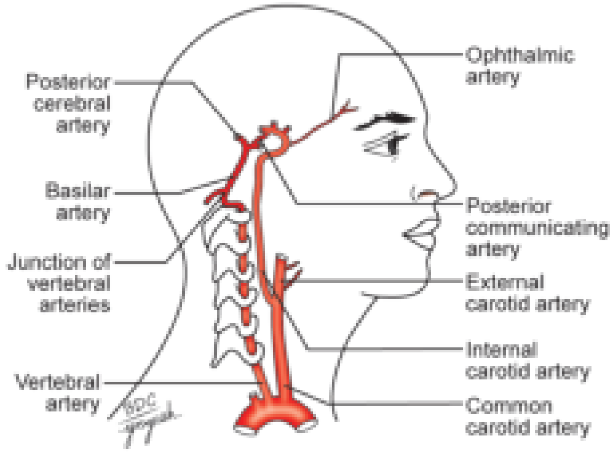

Posterior cerebral artery
Basilar artery
Junction of vertebral arteries
Vertebral artery
Ophthalmic artery
Posterior communicating artery
External carotid artery
Internal carotid artery
Common carotid artery

Fig. 14.1: Carotid and vertebral arteries

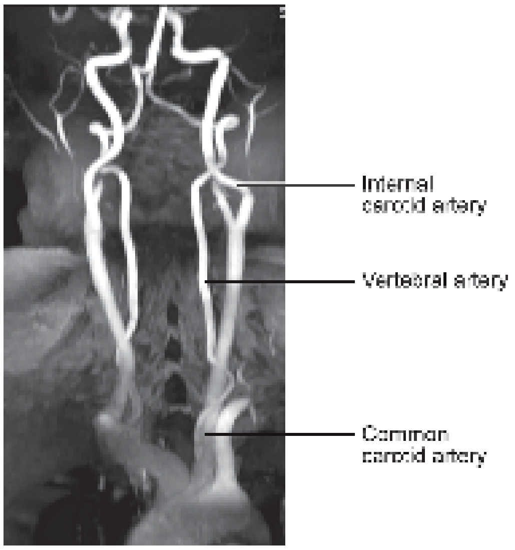

Internal carotid artery
Vertebral artery
Common carotid artery

Fig. 14.2: MRI of the arteries of brain

It enters the subarachnoid space in the upper part of vertebral canal after piercing the dura mater and arachnoid mater. Then it curves round the ventrolateral aspect of the medulla oblongata between the rootlets of hypoglossal nerve, to unite with its fellow at the lower border of pons and forms the median basilar artery.

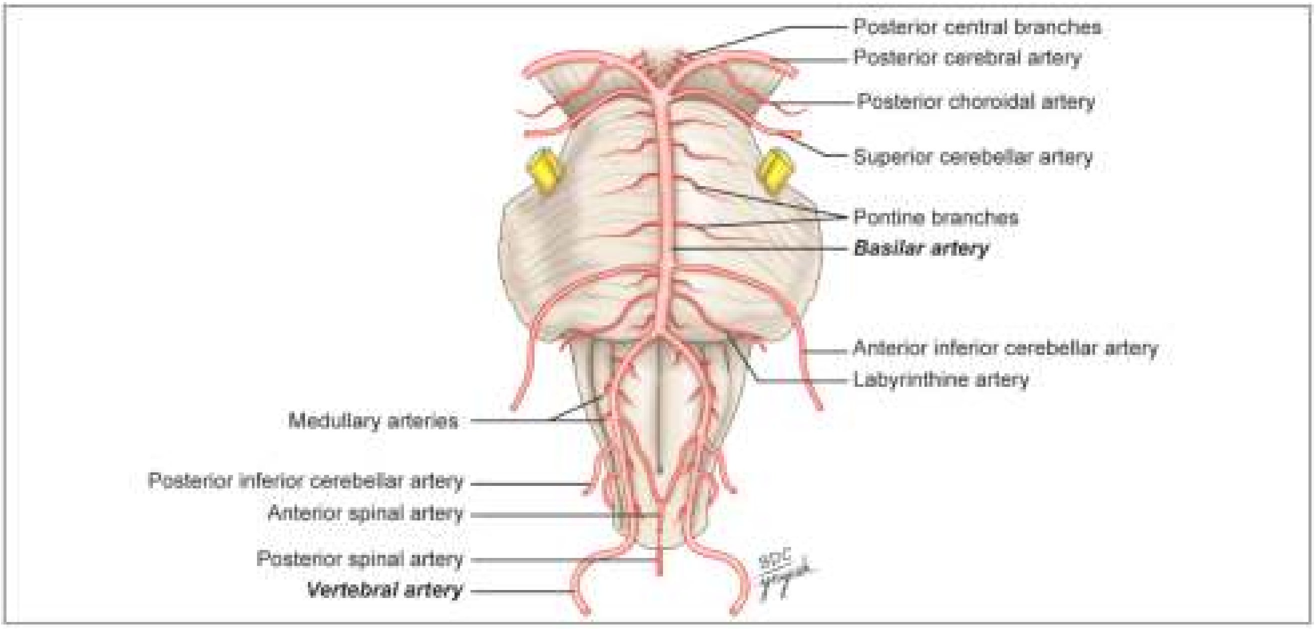
Intracranial Branches of Vertebral Artery

1. Posterior spinal artery
2. Posterior inferior cerebellar artery
3. Anterior spinal artery
4. Medullary branches
5. Meningeal branches.

Note:

1. *Posterior spinal artery* is the first intracranial branch. It passes inferiorly on the spinal medulla among dorsal roots of spinal nerves.
2. *Posterior inferior cerebellar artery* is the largest branch which arises from vertebral artery after it pierces the meninges. It pursues a tortuous course, passes between rootlets of hypoglossal, vagus and glossopharyngeal nerves; supplies almost lateral half of medulla as far as the lower border of pons, reaches its posterior aspect between the thin roof of cavity of fourth ventricle and cerebellum, gives a choroidal branch to

Plate 14.1: Branches of vertebral and basilar arteries (anterior view of brainstem)


Posterior central branches
Posterior cerebral artery
Posterior choroidal artery
Superior cerebellar artery
Pontine branches
Basilar artery
Anterior inferior cerebellar artery
Labyrinthine artery
Medullary arteries
Posterior inferior cerebellar artery
Anterior spinal artery
Posterior spinal artery
Vertebral artery

the choroid plexus of 4th ventricle and turns downwards on the cerebellum supplying it.

3. *Anterior spinal artery* is formed by the union of a branch from each vertebral artery on ventral surface of medulla oblongata close to the pons. It supplies the median part of medulla oblongata and continues inferiorly throughout the length of spinal medulla/cord.
4. *Medullary branches*: As vertebral artery ascends along medulla oblongata, it gives number of branches to the medulla oblongata.
5. *Meningeal branches* of vertebral artery supply the meninges.

BASILAR ARTERY

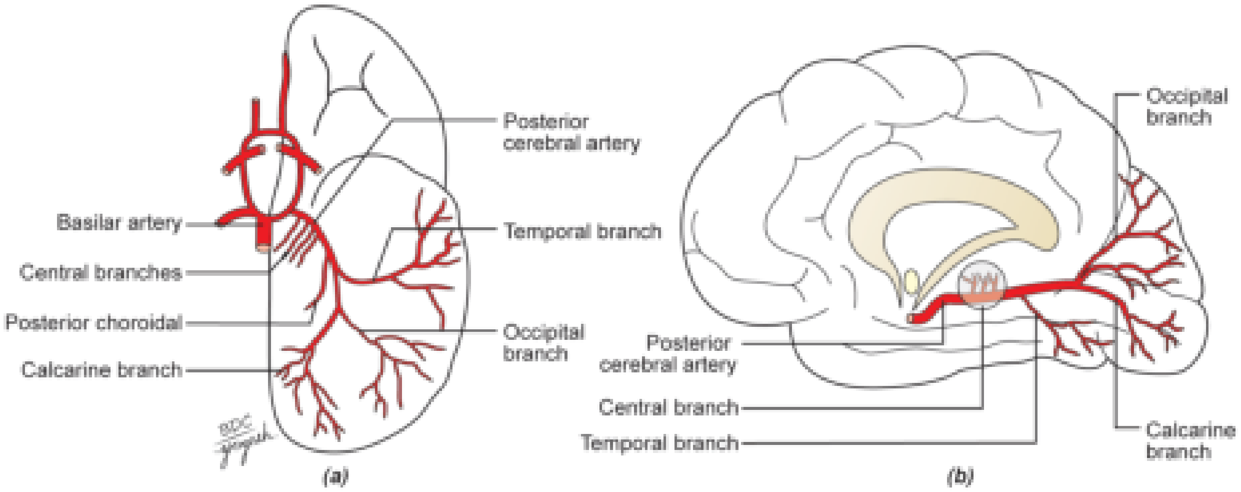
It is formed by the union of two vertebral arteries at the lower border of pons. It lies in the median groove of pons in *cisterna pontis* and at the upper border of pons ends by dividing into two posterior cerebral arteries (Plate 14.1 and Figs 14.3a and b).

Branches

1. Pontine branches
2. Anterior inferior cerebellar artery
3. Labyrinthine artery
4. Superior cerebellar artery
5. Posterior cerebral artery
    a. Posterior central branches
    b. Posterior choroid artery
    c. Cortical branches: Temporal, parieto-occipital, occipital, calcarine branches.

Note:

1. *Anterior inferior cerebellar artery* arises at the lower border of pons, and passes laterally, supplying the sixth, seventh and eighth cranial nerves. It then loops over the flocculus of cerebellum and supplies anteroinferior aspect of cerebellum.
2. *Labyrinthine artery* accompanies the vestibulocochlear nerve and enters the internal auditory meatus to supply the internal ear. It is an end artery.


Posterior cerebral artery
Basilar artery
Temporal branch
Central branches
Posterior choroidal
Occipital branch
Calcarine branch
(a)
Occipital branch
Posterior cerebral artery
Central branch
Temporal branch
Calcarine branch
(b)

Figs 14.3a and b: Posterior cerebral artery on: (a) Inferior surface of left cerebral hemisphere and (b) medial surface of right cerebral hemisphere

3. *Pontine branches* are numerous slender branches that pierce the pons both in the medial and lateral parts.
4. *Superior cerebellar artery* arises close to superior border of pons. It winds posteriorly along the superior border of pons and middle cerebellar peduncle, supplying both. It sends many branches to the superior surface of cerebellum.
5. *Two terminal branches – posterior cerebral branches* diverge at upper border of pons*:* These give rise to number of central (posteromedial group) branches into the ventral surface of midbrain and then curve posterolateral to midbrain at inferomedial surface of corresponding hemisphere supplying it with cortical branches.

   Branches of posterior cerebral arteries
   a. *Posteromedial central branches* pierce ventral surface of base of brain, thus forming the *posterior perforated substance* in the interpeduncular fossa. These supply midbrain and caudal part of diencephalon.
   b. *Posterior choroidal artery* arises on the lateral aspect of central branches, supplies choroid plexus of the lateral ventricle and the third ventricle.
   c. *Cortical branches,* namely temporal branches, parietooccipital branch and occipital branch to cerebral cortex.

CLINICAL NEUROANATOMY

- Thrombosis of posterior cerebral artery results in homonymous hemianopia on the opposite side.
- Thrombosis of superior cerebellar artery results in:
  a. Cerebellum: Disturbed gait, limb ataxia (Fig. 14.4).
  b. Brainstem: Ipsilateral Horner's syndrome. Contralateral sensory loss—pain and temperature (including face).
- Damage to anterior inferior cerebellar artery results in (Fig. 14.5):
  a. Cerebellum: Ipsilateral limb ataxia.
  b. Brainstem: Ipsilateral Horner's syndrome.
  Sensory loss—pain and temperature of face.
  Facial weakness and paralysis of lateral gaze.
  Contralateral sensory loss—pain and temperature of limbs and trunk.
- Thrombosis of posterior inferior cerebellar artery causes damage as given in Fig. 14.6:
  a. Cerebellum: Dysarthria, ipsilateral limb ataxia, vertigo and nystagmus (due to damage to vestibulofloccular connections).
  b. Brainstem: Ipsilateral Horner's syndrome.
  Sensory loss—pain and temperature of face.
  Pharyngeal and laryngeal paralysis.
  Contralateral sensory loss—pain and temperature of limbs and trunk.

INTERNAL CAROTID ARTERY

Each internal carotid artery enters the cranial cavity after traversing the carotid canal and superior aspect of foramen lacerum. It then courses through the cavernous sinus, pierces the dural roof of sinus and ends immediately lateral to optic chiasma and inferior to anterior perforated substance and divides into middle and anterior cerebral arteries.

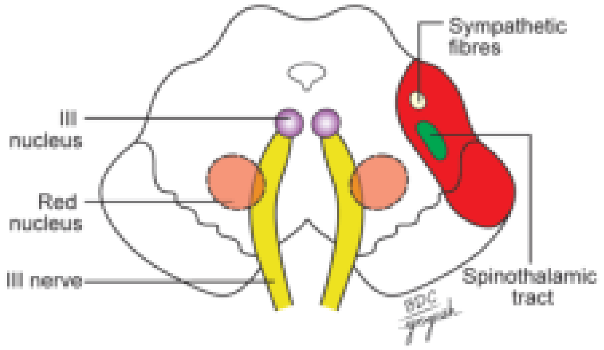


Fig. 14.4: Effects due to thrombosis of superior cerebellar artery

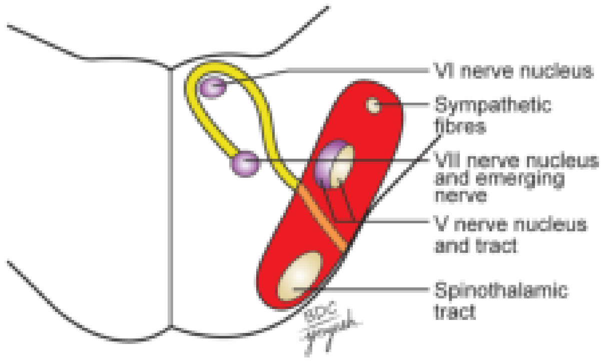

VI nerve nucleus
Sympathetic fibres
VII nerve nucleus and emerging nerve
V nerve nucleus and tract
Spinothalamic tract
BDC

Fig. 14.5: Effects due to damage to anterior inferior cerebellar artery

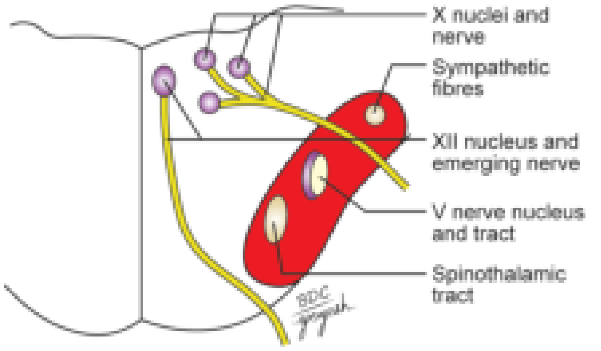


Fig. 14.6: Effects due to thrombosis of posterior inferior cerebellar artery

Branches

1. Ophthalmic artery
2. Anterior choroidal artery
3. Posterior communicating artery
4. Anterior cerebral artery
5. Middle cerebral artery.

Note:
1. *Ophthalmic artery* for the contents of orbit (For details, *see* Chapter 13, *BD Chaurasia's Human Anatomy*, *Volume 3*).
2. *Posterior communicating artery* passes posteriorly across the crus cerebri to join the posterior cerebral artery and helps to complete the arterial circle. It gives branches to the crus cerebri, optic tract, hypophysis and hypothalamus.
3. *Anterior choroidal artery* passes posterolaterally, supplies crus cerebri and turns laterally to the medial aspect of temporal lobe to supply choroid plexus of inferior horn of lateral ventricle.

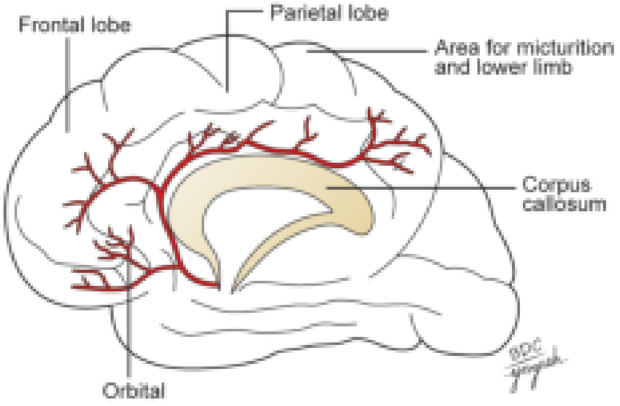
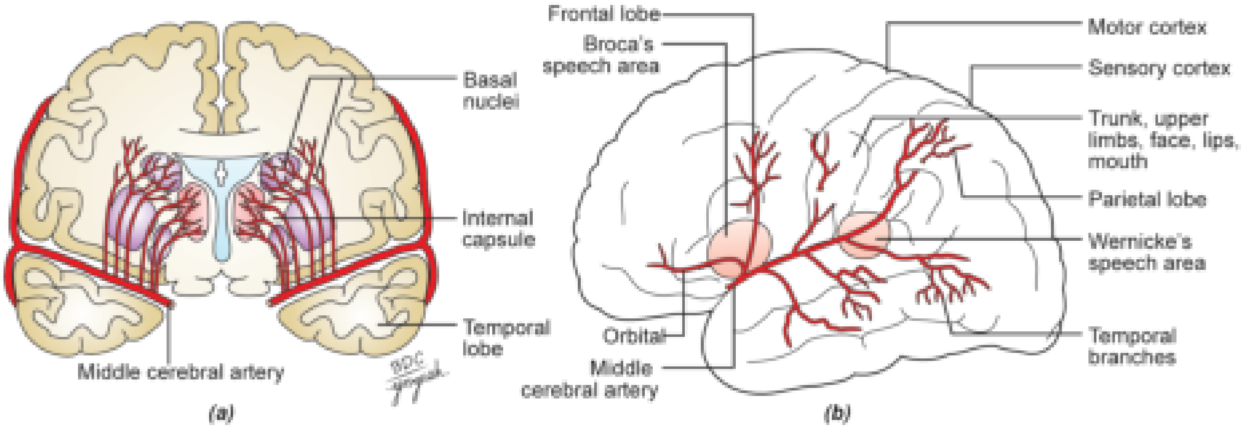

Frontal lobe
Parietal lobe
Area for micturition and lower limb
Corpus callosum
Orbital

Fig. 14.7: Medial surface of right cerebral hemisphere with anterior cerebral artery


Basal nuclei
Internal capsule
Temporal lobe
Middle cerebral artery
(a)
Frontal lobe
Broca's speech area
Orbital
Middle cerebral artery
Motor cortex
Sensory cortex
Trunk, upper limbs, face, lips, mouth
Parietal lobe
Wernicke's speech area
Temporal branches
(b)

Figs 14.8a and b: (a) Deep branches of middle cerebral artery and (b) cortical branches of middle cerebral artery

4. *Anterior cerebral artery* is a terminal branch of internal carotid artery and runs above the optic nerve to follow the curve of corpus callosum. Close to its origin, this artery is joined by anterior communicating artery. Anteromedial central branches of anterior cerebral artery supply part of internal capsule and the basal nuclei. Cortical branches supply the medial surface of hemisphere by giving: Orbital, frontal, and parietal branches (Fig. 14.7).
5. *Middle cerebral artery* is the larger terminal branch of internal carotid artery that lies in line with the internal carotid artery (Figs 14.8a and b). It runs laterally in the stem of lateral sulcus. It gives off *deep or perforating branches* which supply anterior limb of internal capsule and part of basal nuclei. The artery then passes out to the lateral surface of hemisphere at the insula of the lateral sulcus. It ends by giving cortical branches to: Temporal lobe, frontal lobe, and parietal lobe.

***Competency*:**
AN62.6 Describe and identify formation, branches and major areas of distribution of circle of Willis.

CIRCULUS ARTERIOSUS OR CIRCLE OF WILLIS

It is a hexagonal arterial circle, situated at the base of brain in the interpeduncular fossa (Figs 14.9 to 14.11).

Formation

- *Anteriorly*: Anterior communicating artery joining the two anterior cerebral arteries

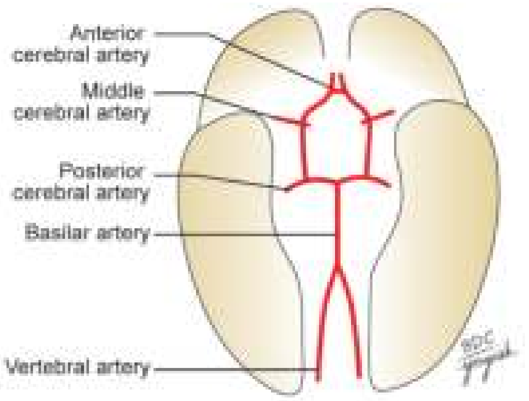

Anterior cerebral artery
Middle cerebral artery
Posterior cerebral artery
Basilar artery
Vertebral artery

Fig. 14.9: Arteries seen on the inferior surface of brain

- *Anterolaterally*: Anterior cerebral arteries
- *Laterally*: Internal carotid arteries
- *Posterolaterally*: Posterior communicating arteries
- *Posteriorly*: Posterior cerebral arteries.

Note: Middle cerebral artery is not forming the circle of Willis.

Functional Significance

The circulus arteriosus attempts to equalize the flow of blood to different parts of brain and provides a collateral circulation in the event of obstruction to one of its components. There is hardly any mixing of bloodstreams on right and left sides of the circulus arteriosus.

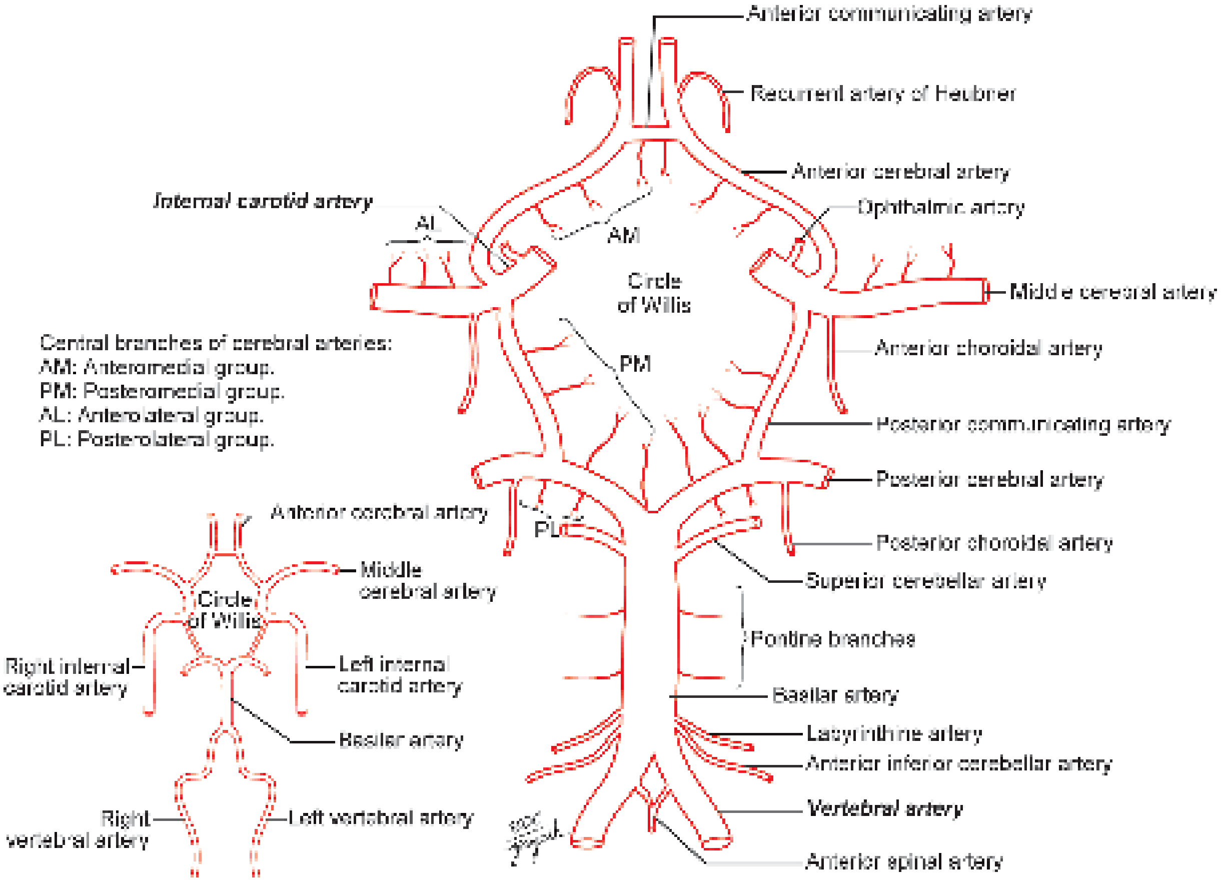

Anterior communicating artery
Recurrent artery of Heubner
Anterior cerebral artery
Ophthalmic artery
Internal carotid artery
AL
AM
Circle of Willis
Middle cerebral artery
Anterior choroidal artery
PM
Central branches of cerebral arteries:
AM: Anteromedial group.
PM: Posteromedial group.
AL: Anterolateral group.
PL: Posterolateral group.
Posterior communicating artery
Posterior cerebral artery
Anterior cerebral artery
PL
Posterior choroidal artery
Middle cerebral artery
Circle of Willis
Superior cerebellar artery
Pontine branches
Right internal carotid artery
Left internal carotid artery
Basilar artery
Basilar artery
Labyrinthine artery
Anterior inferior cerebellar artery
Vertebral artery
Right vertebral artery
Left vertebral artery
Anterior spinal artery

Fig. 14.10: Circle of Willis and the branches of arteries supplying the brain

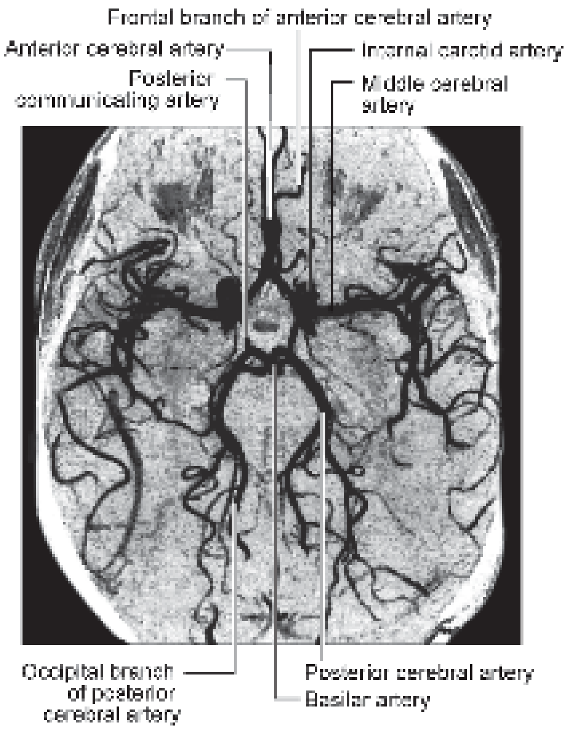

Frontal branch of anterior cerebral artery
Anterior cerebral artery
Internal carotid artery
Posterior communicating artery
Middle cerebral artery
Occipital branch of posterior cerebral artery
Posterior cerebral artery
Basilar artery

Fig. 14.11: Magnetic resonance angiogram of the cerebral blood vessels

Branches

The branches of the circulus arteriosus are cortical, central and choroidal.

1. Cortical branches run on the surface of cerebral hemispheres (Table 14.1).
2. Central branches perforate the white matter to supply thalamus, basal ganglia, and internal capsule. These are grouped as follows:
    - Anteromedial group
    - Two anterolateral groups
    - Posteromedial group
    - Two posterolateral groups.
3. Choroidal branches supply the choroid plexuses of the various ventricles. These are:
    - Anterior choroidal is a branch of internal carotid artery.
    - Posterior choroidal is a branch of posterior cerebral artery.

[*Mnemonics:* ***Cell is Clearly Circulating:*** **C** – Cortical branches; **C** – Central branches; **C** – Choroidal branches]

Important arteries of the brain are shown in Table 14.1.

Note:

The cortical branches anastomose freely and if these get blocked, they give rise to small infarcts.

The central branches do not anastomose and if these get blocked, they give rise to large infarcts.

Central Branches

1. *Anteromedial (AM) group* arises as one group from both anterior cerebral and anterior communicating arteries. These enter the medial most part of anterior perforated substance to supply anterior part of lentiform nucleus and head of caudate nucleus.

TABLE 14.1: Important arteries of brain

Artery	*Origin*	*Course*	*Cortical branches*
Middle cerebral	Largest and direct continuation of ICA	In the lateral sulcus and on the insula	1. Orbital 2. Frontal 3. Parietal 4. Temporal
Anterior cerebral	Smaller terminal branch of ICA	Follow the curve of the corpus callosum. Two arteries are connected by the anterior communicating artery	1. Orbital 2. Frontal 3. Parietal, including paracentral artery
Posterior cerebral	Terminal branch of basilar artery	Winds around cerebral peduncle to reach the tentorial surface of cerebrum	1. Temporal 2. Occipital 3. Parieto-occipital

The branch to head of caudate nucleus is called recurrent artery of Heubner. It also supplies rostral part of internal capsule.

2. *Anterolateral group* arises in two groups—one group from each middle cerebral artery. These pierce the anterior perforated substance and supply the corpus striatum and the internal capsule. These branches are called lateral striate arteries. One of the lateral striate branches is larger than the others and is called Charcot's artery of cerebral haemorrhage.
3. *The posteromedial (PM) group* arises as *one group* from posterior communicating and posterior cerebral arteries. These supply tuberoinfundibular and mammillary regions of hypothalamus, subthalamus, anterior and medial parts of thalamus, medial part of tegmentum and crus cerebri of midbrain.
4. *Posterolateral (PL) group* arises as *two groups* from the lateral parts of each posterior cerebral artery. These supply caudal part of thalamus.

Choroidal Branches

1. The anterior choroidal is a branch of internal carotid artery. It supplies blood to choroid plexus of inferior horn of lateral ventricle.
2. Posterior choroidal artery arises from posterior cerebral artery to give branches for the choroid plexus of rest of lateral ventricle including third ventricle.
3. Posterior inferior cerebellar artery supplies the choroid plexus of the fourth ventricle.

ARTERIAL SUPPLY OF DIFFERENT AREAS

Cerebral cortex is supplied by branches from all three arteries (Figs 14.12a to c).

Superolateral surface: This surface is mostly supplied by middle cerebral. Areas *not* supplied by this artery are as under:

i. A strip of about 2 cm wide along the superomedial border extending from frontal pole to the parieto-occipital sulcus is supplied by anterior cerebral artery.
ii. Area of occipital lobe is supplied by posterior cerebral artery.
iii. Inferior temporal gyrus excluding the part of the temporal pole is also supplied by posterior cerebral artery.
iv. Rest of the big area is supplied by middle cerebral artery.

Medial and tentorial surfaces: The main artery here is the anterior cerebral. The medial aspects of the occipital lobe, temporal lobe except area around temporal pole is supplied by posterior cerebral artery. Temporal pole area gets nourished by middle cerebral artery.

Inferior surface: Medial one-third of orbital surface is supplied by anterior cerebral, while lateral two-thirds, including the temporal pole area and anterior most part of tentorial surface is vascularised by middle cerebral artery. Rest of the tentorial surface is supplied by the posterior cerebral artery.

Cerebral Cortex

Cerebral cortex is supplied by branches of all three cerebral arteries. All the three surfaces receive branches from all three arteries.

Middle cerebral is main artery on superolateral surface.

Anterior cerebral artery is chief artery on medial surface.

Posterior cerebral is the principal artery on inferior surface.

Cerebellum

The little brain is supplied by the following arteries (Fig. 14.13):

1. Superior cerebellar
2. Anterior inferior cerebellar
3. Posterior inferior cerebellar.

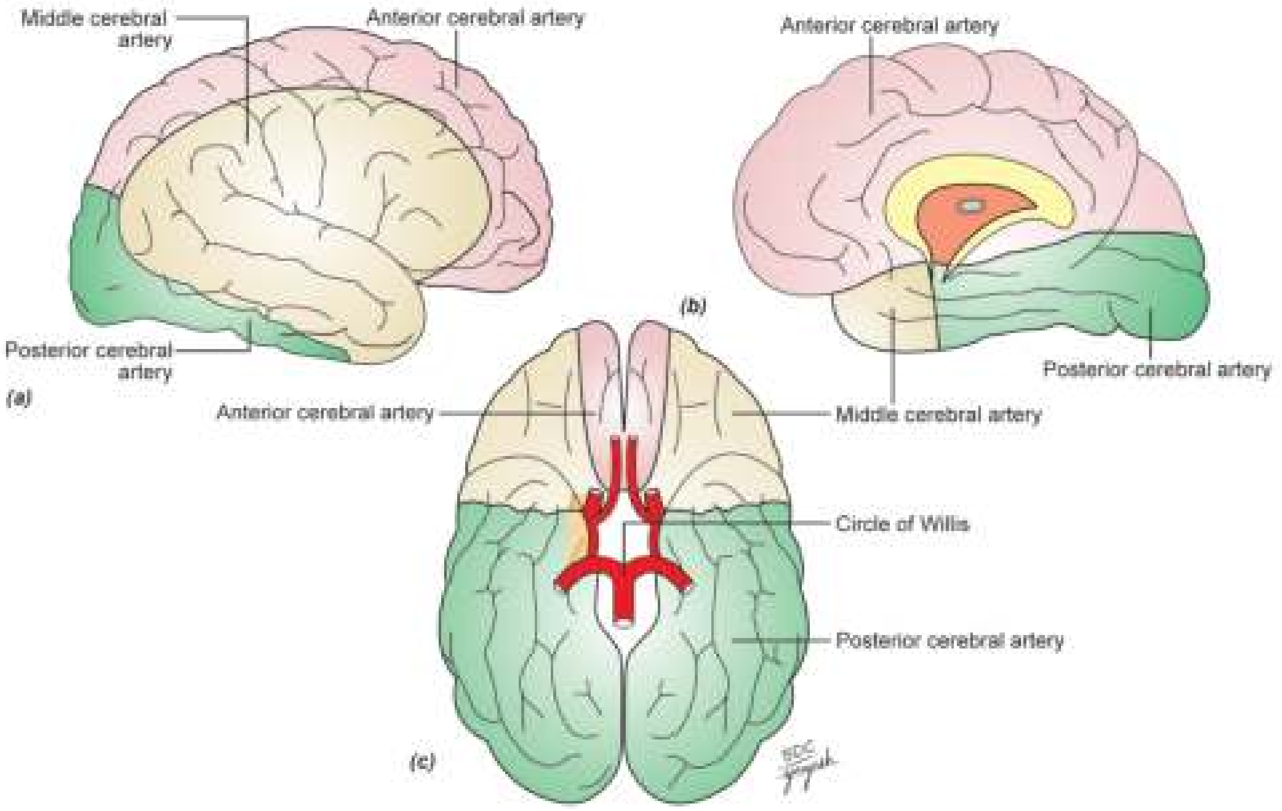
BLOOD–BRAIN BARRIER (BBB)

The constituents of CSF are not exactly the same as those of extracellular fluid (ECF) elsewhere in the body. Many large molecular substances hardly pass from blood to CSF or interstitial fluids of brain even though these can pass to ECF of the body, thereby reflecting the existence of BBB (Fig. 14.14).

Components

The existence of a 'blood–brain barrier' (BBB or haematoencephalic barrier) is because the endothelial cells of brain capillaries are held to each other by tight junctions. The BBB is formed by structures between the blood and nerve cells of brain. The blood in the lumen of the capillary is separated from the neurons by:

a. Capillary endothelium
b. Basement membrane of endothelium


Middle cerebral artery
Anterior cerebral artery
Anterior cerebral artery
Posterior cerebral artery
(a)
(b)
Posterior cerebral artery
Anterior cerebral artery
Middle cerebral artery
Circle of Willis
Posterior cerebral artery
(c)

Figs 14.12a to c: Arterial supply of cerebral hemisphere: (a) Superolateral surface, (b) medial and tentorial surfaces, and (c) inferior surface

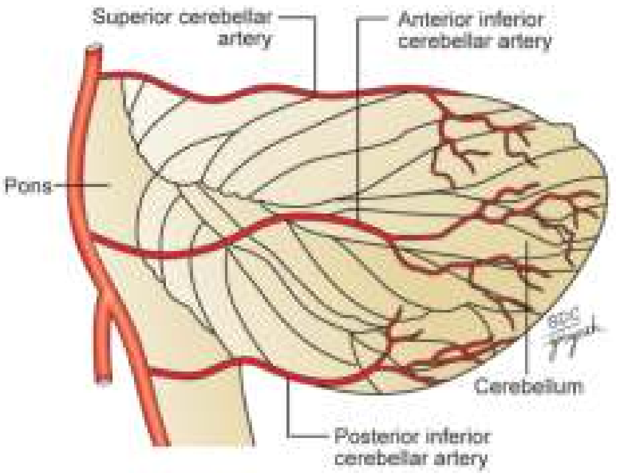

Superior cerebellar artery
Anterior inferior cerebellar artery
Pons
Cerebellum
Posterior inferior cerebellar artery

Fig. 14.13: Arterial supply of cerebellum

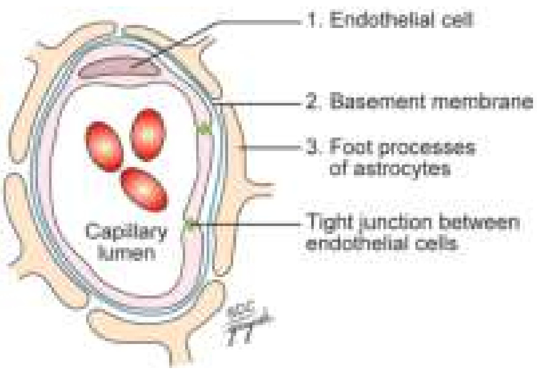

1. Endothelial cell
2. Basement membrane
3. Foot processes of astrocytes
Capillary lumen
Tight junction between endothelial cells

Fig. 14.14: Blood–brain barrier

c. Intimately applied to the capillaries, there are numerous processes of astrocytes and it has been estimated that these processes cover about 80% of the capillary surface.

Functions of Blood–Brain Barrier

1. To modulate entry of metabolic substrates, notably glucose.
2. It allows entry of gases, water, electrolytes, amino acids and lipid-soluble substances.
3. It restricts entry of macromolecules, i.e. lipid insoluble substances and thus blocks entry of toxins as either these are bound to the plasma albumin or their solubilities are inappropriate.
4. It blocks entry of transmitters from blood, notably of epinephrine.
5. The drugs like penicillin, noradrenaline and thiopentone cannot cross it.
6. Some drugs like atropine, chloramphenicol, tetracycline and sulphas cross the barrier easily.
7. Its other important function is to pump ions—notably potassium into and out of the blood.
8. Entry of hormones is restricted to certain places only, so that normal biological rhythm of the body is maintained.

Note: Some areas of brain are devoid of blood–brain barrier. These include pineal body, hypophysis cerebri, choroid plexuses and area postrema in fourth ventricle of brain. BBB exists in newborn but is more permeable to certain substances than it is in adult.

PERIVASCULAR SPACES

1. The ***perivascular spaces (Virchow-Robin)*** are extensions of subarachnoid space around vessels penetrating the brain surface. The spaces taper progressively. Although these are inward extensions in anatomical sense. The subarachnoid and perivascular spaces are separated by a thin layer of pia mater. The flow of extracellular fluid is outward into the subarachnoid space.

   The perivascular spaces are involved in autoregulation of brain arterioles which regulates the blood supply to tissues.
2. The chief internal source of autoregulation is the adjustment of arterial muscle tone in response to intraluminal pressure changes. Cerebral blood flow remains at 60–70 ml/100 g/min during systemic blood pressure; changes ranging from 80 to 180 mm Hg. This is achieved by a direct myogenic response to distension produced by rising intraluminal pressure.
3. The H^+ ion concentration in the perivascular space is the chief external source of autoregulation of cerebral blood vessels. A rising H^+ (usually following hypercapnia—excess plasma CO_2) travels along perivascular space from the capillary bed and it inhibits vascular muscle, perhaps by reducing ionized calcium level. On the other hand, hypocapnia causes vasoconstriction.

CLINICAL NEUROANATOMY

- Thrombosis of lateral striate branches of middle cerebral artery causes motor and sensory loss to most of the opposite side of body.
- Hemiplegia is a common condition. It is an upper motor neuron type of paralysis of one-half of the body, including the face. It is usually due to an internal capsule lesion caused by thrombosis of one of the lateral striate branches of middle cerebral artery (cerebral thrombosis) (Fig. 14.15). One of the lateral striate branches is most frequently ruptured (cerebral haemorrhage); it is known as ***Charcot's artery of cerebral haemorrhage***. This lesion also produces hemiplegia with deep coma, and is ultimately fatal.
- Thrombosis of Heubner's recurrent branch of the anterior cerebral artery causes contralateral upper limb monoplegia.
- Occlusion of anterior cerebral artery proximal to the anterior communicating artery is normally well tolerated because of the cross flow.
- Distal occlusion of anterior cerebral artery results in weakness and cortical sensory loss in the contralateral lower limb with associated incontinence (Figs 14.16a and b). This artery supplies the area of lower limb and perineum.
- Thrombosis of the paracentral artery (terminal cortical branch of the anterior cerebral artery) causes contralateral lower limb monoplegia.

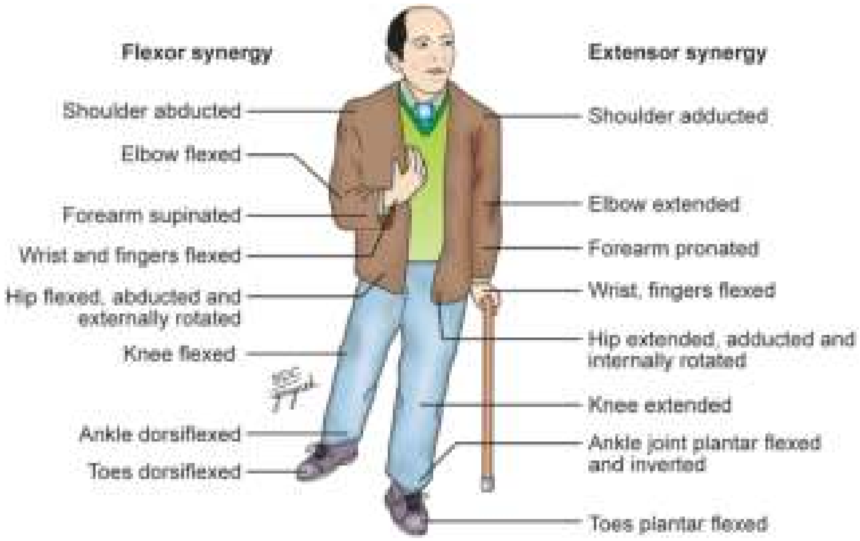
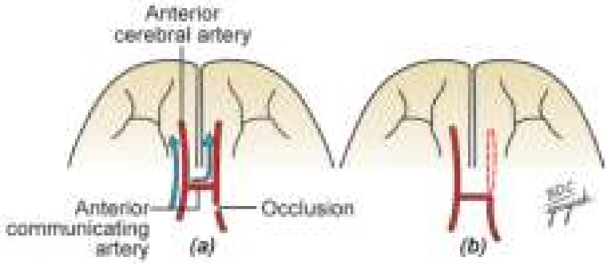

Flexor synergy
Shoulder abducted
Elbow flexed
Forearm supinated
Wrist and fingers flexed
Hip flexed, abducted and externally rotated
Knee flexed
Ankle dorsiflexed
Toes dorsiflexed
Extensor synergy
Shoulder adducted
Elbow extended
Forearm pronated
Wrist, fingers flexed
Hip extended, adducted and internally rotated
Knee extended
Ankle joint plantar flexed and inverted
Toes plantar flexed

Fig. 14.15: Posture of hemiplegic person


Anterior cerebral artery
Anterior communicating artery
Occlusion
(a)
(b)

Figs 14.16a and b: Effects of occlusion of anterior cerebral artery

VEINS OF THE BRAIN

Characteristics of the Veins of Brain

1. The walls are devoid of muscle.
2. The veins have no valves.
3. To maintain patency, some of them open into the cranial venous sinuses against the direction of blood flow in the sinus, e.g. the superior cerebral veins draining into the superior sagittal sinus.

Groups of Veins (Figs 14.17 to 14.19)

External Cerebral Veins

1. ***Superior cerebral veins:*** These are 6 to 12 in number. They drain the superolateral surface of the hemisphere. They terminate in the superior sagittal sinus.
2. ***Superficial middle cerebral vein:*** This drains the area around the posterior ramus of the lateral sulcus. It terminates in the cavernous sinus, or at times into the sphenoparietal sinus. Through the superior and inferior anastomotic veins, it communicates with the superior sagittal and transverse sinuses. It also communicates with the deep middle cerebral vein.
3. ***Deep middle cerebral vein:*** This drains the surface of the insula and terminates in the basal vein.
4. ***Inferior cerebral veins:*** These are several in number. They are divided into orbital and tentorial veins. The orbital veins terminate in the superior cerebral veins or in the superior sagittal sinus. The tentorial veins terminate in the cavernous or any other surrounding sinus.
5. ***Anterior cerebral veins:*** These are small veins which drain the corpus callosum and the anterior part of the medial surface of the hemisphere. They terminate in the basal vein (Fig. 14.19).

Internal Cerebral Veins

There is one vein on each side. It is formed by the union of the thalamostriate and choroidal veins at the apex of the tela choroidea of the third ventricle. The right and left veins run posteriorly parallel to each other in the tela choroidea, and unite together to form the great cerebral vein below the splenium of the corpus callosum (Fig. 14.20). Great cerebral vein joins with inferior sagittal sinus to form straight sinus which forms left transverse sinus. It continues as left sigmoid sinus to continue as internal jugular vein on left side.

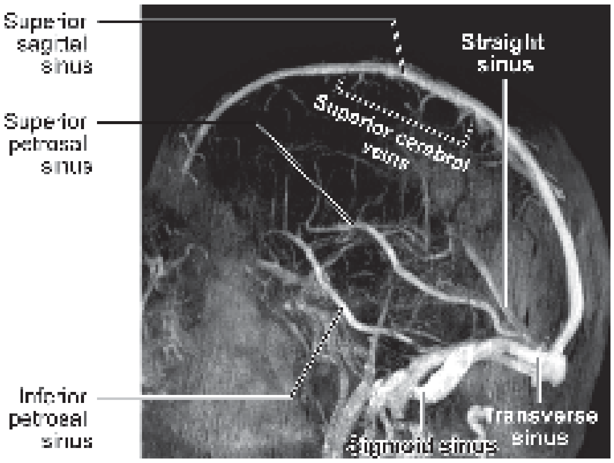

Superior sagittal sinus
Superior petrosal sinus
Inferior petrosal sinus
Straight sinus
Superior cerebral veins
Transverse sinus
Sigmoid sinus

Fig. 14.18: MRI of veins of brain

Terminal Veins

1. ***Great cerebral vein of Galen:*** This is a single median vein. It is formed by union of the two internal cerebral veins. It terminates in the straight sinus. Its tributaries include the basal veins, and veins from the pineal body, the colliculi, the cerebellum and the adjoining part of the occipital lobes of the cerebrum.
2. ***Basal vein:*** There is one vein on each side. It is formed at the anterior perforated substance by the union of the deep middle cerebral vein, the anterior cerebral veins, and the striate veins. It runs posteriorly, winds round the cerebral peduncle, and terminates by joining the great cerebral vein. Its tributaries include (apart from the veins forming it) small veins from the cerebral peduncle, interpeduncular structures, the tectum of the midbrain, and the parahippocampal gyrus.
3. Ultimately, all veins drain into the various cranial venous sinuses which, in turn, drain into the internal jugular vein.

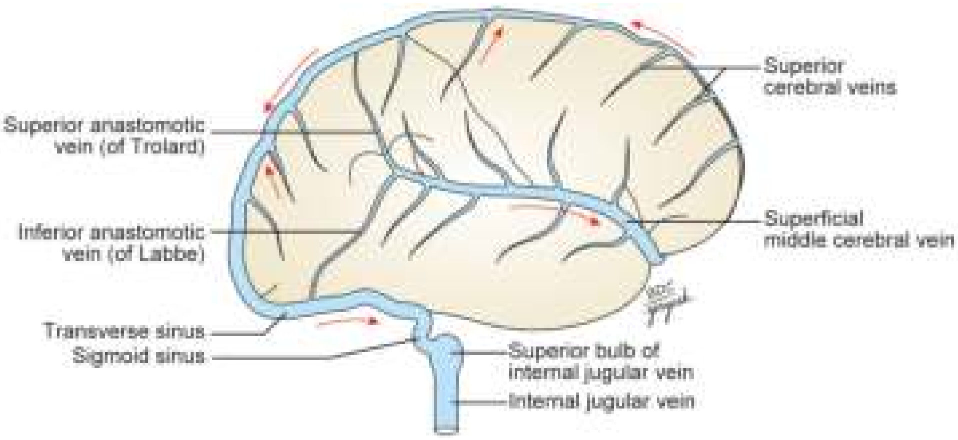

Superior cerebral veins
Superior anastomotic vein (of Trolard)
Superficial middle cerebral vein
Inferior anastomotic vein (of Labbe)
Transverse sinus
Sigmoid sinus
Superior bulb of internal jugular vein
Internal jugular vein

Fig. 14.17: Veins on the superolateral surface of the cerebral hemisphere (right lateral view, red arrows indicate direction of blood flow)

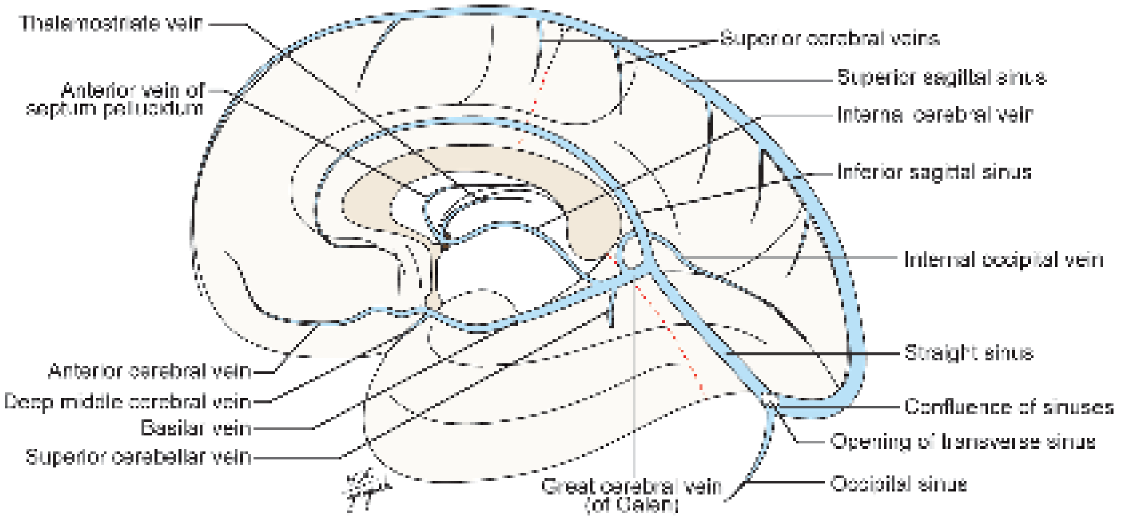

Thalamostriate vein
Anterior vein of septum pellucidum
Anterior cerebral vein
Deep middle cerebral vein
Basilar vein
Superior cerebellar vein
Great cerebral vein (of Galen)
Superior cerebral veins
Superior sagittal sinus
Internal cerebral vein
Inferior sagittal sinus
Internal occipital vein
Straight sinus
Confluence of sinuses
Opening of transverse sinus
Occipital sinus

Fig. 14.19: Veins on the medial surface of right cerebral hemisphere

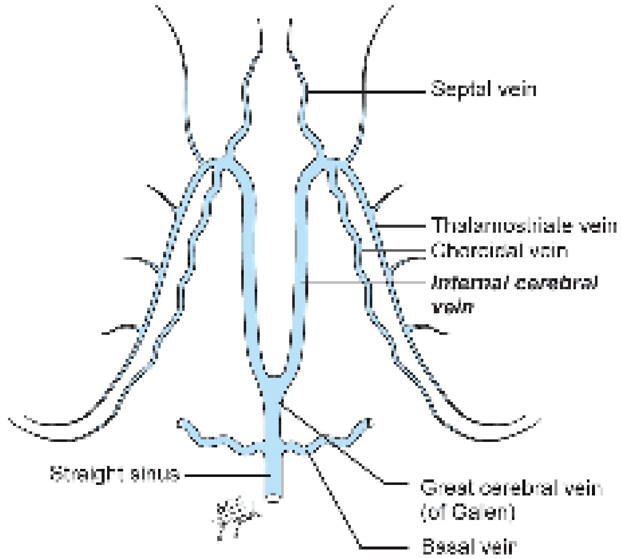

Septal vein
Thalamostriate vein
Choroidal vein
Internal cerebral vein
Straight sinus
Great cerebral vein (of Galen)
Basal vein

Fig. 14.20: Internal cerebral veins

BLOOD SUPPLY OF THE BRAINSTEM

Midbrain: The midbrain is supplied by branches from the posterior cerebral arteries, including their central branches, both posteromedial and posterolateral.

Pons: The pons is supplied by the pontine branches of basilar artery.

Medulla: The medulla is supplied by:

a. The medullary branches of the vertebral artery.
b. Branches from the posterior inferior cerebellar artery.

The veins of the brainstem drain into neighbouring venous sinuses.

CLINICAL NEUROANATOMY

- ***Anastomotic and end arteries***: In the circle of Willis, the blood in the three communicating arteries is normally static. Following occlusion of one of the three large arteries contributing to the circle, the other two compensate more or less completely, via communicating arteries. With occlusion of one internal carotid, the other internal carotid may perfuse both anterior cerebral arteries. With occlusion of basilar, each posterior cerebral artery may be perfused by the internal carotid of its own side.

  Further anastomosis occurs between cortical branches of cerebral arteries, prior to perforation of the branches into brain substance. Once the cortical and central branches perforate, they become end arteries hardly communicating at capillary level.
- ***Cerebral vascular disease*** is quite common in old age and manifest in different ways.
  a. Haemorrhage—cortical or subcortical
  b. Thrombosis
  c. Embolism.
- Hypertensive encephalopathy is a manifestation of sustained elevation of diastolic blood pressure in the form of multiple diffuse small lesions distributed all over, result in a variegated picture of the circle of Willis (***Berry's aneurysm***).
- The arteries of the brain are supplied with sympathetic nerves which run onto them from carotid and vertebral plexuses. They are extremely sensitive to injury and readily react by passing into prolonged spasms. This by itself may be sufficient to cause damage to brain tissue since even the least sensitive neurons cannot withstand absolute loss of blood supply for a period more than 3–7 minutes.

Video 4.11 Blood Supply of Brain

Facts to Remember

- Posterior inferior cerebellar artery is the largest branch of vertebral artery. It supplies posterolateral part of medulla oblongata, lower part of pons, inferior surface of cerebellum including choroidal branches to 4th ventricle.

- Posterior cerebral arteries are the terminal branches of the basilar artery and supply the visual cortex.
- Middle cerebral artery is the larger terminal branch of internal carotid and supplies most of the superolateral surface of the cerebral cortex.
- Anterior cerebral artery is the smaller terminal branch of the internal carotid artery. It runs along the corpus callosum supplying maximum area on the medial surface of the cerebral hemisphere.
- Two lobes of the cerebellum are supplied by 3 pairs of cerebellar arteries. These are superior cerebellar, anterior inferior cerebellar and posterior inferior cerebellar arteries.
- Carotid siphon is the hair-pin bend of the internal carotid artery within the cranial cavity.
- Berry aneurysms is a localized dilatation of arteries of circle of Willis. Its rupture is the commonest cause of intracerebral haemorrhage.
- Charcot's artery is the largest lateral (lenticulostriate artery) and known as a artery of cerebral haemorrhage.
- Artery of cerebral thrombosis is the anterior choroidal artery.

BDC's Anatomy *e*-book

1. Anterior Spinal Artery Syndrome
2. Further reading
3. Viva voce questions.

Chapter 15

Surface Marking and Radiological Anatomy of Nervous System

SURFACE MARKING

The surface anatomy of brain is important in clinical examination for assessing the location of injury and for planning and performing neurosurgery.

Borders of Cerebral Hemisphere

Mark the following points (Fig. 15.1):

Point 1: Just superolateral to inion

Point 2: Just superolateral to nasion

Point 3: At the zygomatic process of frontal bone

Point 4: At pterion

Point 5: At the middle of the upper border of zygomatic arch.

For superomedial border: Join points 1 and 2 by a paramedian line.

For superciliary border: Join points 2 and 3 by upward arched line and extend this line to point 4.

For inferolateral border: Join points 4 and 5 with curved line (convex forward) and then join points 1 and 5 by upward convex line, passing above the external acoustic meatus.

Sulci of Cerebrum

Central sulcus

Mark the following points (Fig. 15.2):

Point 1: At 1.2 cm behind the midpoint of the line joining the nasion with the inion.

Point 2: At 7.5 cm above preauricular point.

For *central sulcus*, draw S-shaped line from point 1 to point 2 running downward and forward making on the angle of 70° with the median plane.

Lateral sulcus

Mark the following points (Fig. 15.3):

Point A: At pterion

Point B: 2 cm below the parietal eminence.

For *lateral sulcus*, point A represents sylvian point and it represents the *stem of the lateral sulcus*.

For the *posterior ramus of the lateral sulcus*, mark 7 cm long line by joining points A and B.

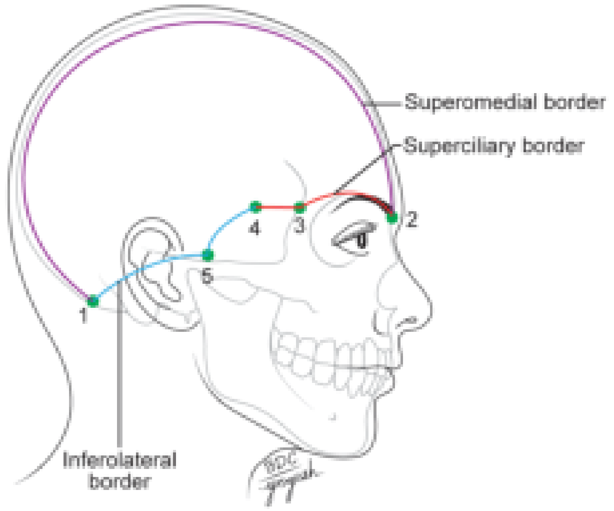


Fig. 15.1: Surface marking of the borders of cerebral hemisphere

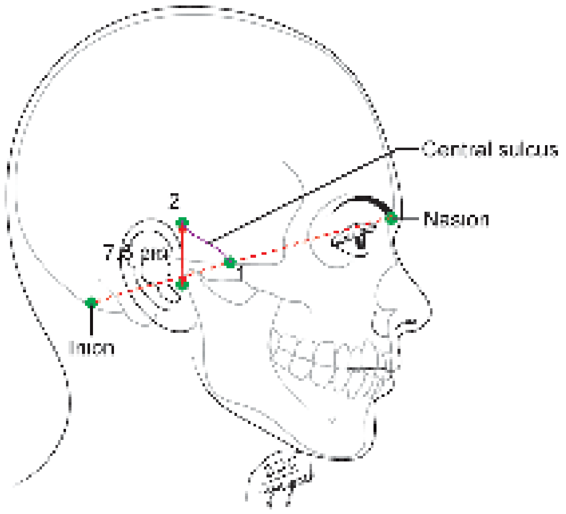


Fig. 15.2: Surface marking of the central sulcus

Functional Areas of Cerebrum (Fig. 15.4)

1. *Motor area*: It is marked by 1 cm wide strip in front of the posterior ramus of lateral sulcus (finger broad).
2. *Sensory area*: It is marked by 1 cm wide strip behind the posterior ramus of lateral sulcus.

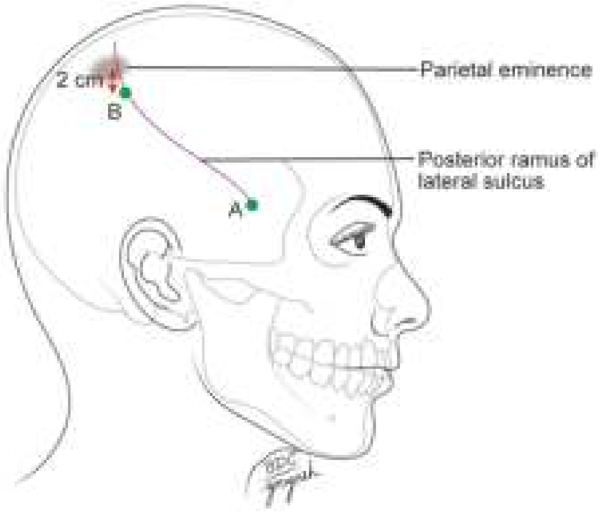


Fig. 15.3: Surface marking of the posterior ramus of lateral sulcus (right lateral view)

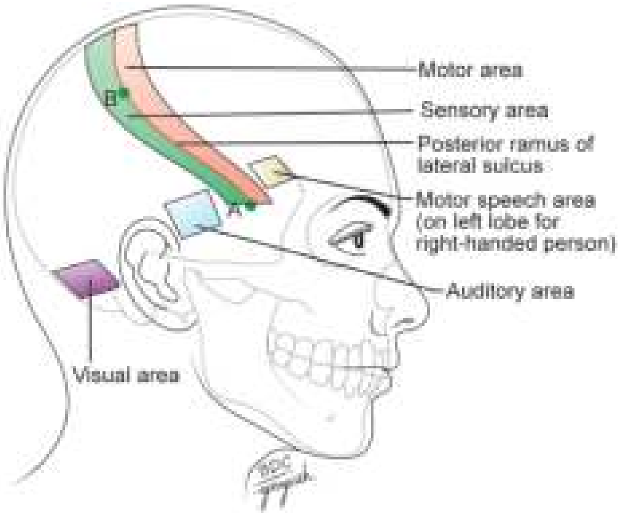

Motor area
Sensory area
Posterior ramus of lateral sulcus
Motor speech area (on left lobe for right-handed person)
Auditory area
Visual area
B
A

Fig. 15.4: Surface marking of the functional areas of the cerebral cortex (right lateral view)

3. *Motor speech area*: It is marked on the left (in right handed person) just above and anterior to the pterion.
4. *Auditory area*: It is marked little above and anterior to the auricle and below the posterior ramus of the lateral sulcus.
5. *Visual area*: It is marked on each side above the external occipital protuberance.

RADIOLOGICAL ANATOMY OF THE BRAIN

IMAGING OF CNS

The imaging of central nervous system is important for diagnosis and treatment of a patient with neurological disorders. Plain radiograph of skull and spine is still basic primary investigation, and they provide many important information in CNS disorders.

Computerised tomography (CT) scan and magnetic resonance imaging (MRI), positron emission tomography (PET scan) and single photon emission computed tomography (SPECT) are useful for neuroimaging.

Functional neuroimaging: It helps in assessing the metabolic and functional activities of brain. It includes EEG (electroencephalography), PET scan, functional MRI, SPECT scan and magnetic resonance spectrography (MRS).

The imaging modalities are useful for:

1. Diagnosis or detection of intracranial tumours, injuries, degenerative diseases, and infections.
2. For detection of activities and functioning of entire brain or a particular area of the brain.
3. To measure the level of different metabolites in the brain or detect metabolic disorders.
4. To determine the neurotransmitter activity in a specific part of brain.

Imaging with Plain X-ray

The anteroposterior (AP), lateral and Towne's (fronto-occipital) views give idea about (Fig. 15.5):

1. Skull bones, bone erosion, fractures, vascular markings
2. Aneurysm of vessels
3. Neurological tumours such as neurogliomas, meningiomas
4. Sites of calcifications – pineal gland, choroid plexus
5. Midline shift.

Imaging with X-ray Contrast Media

A *contrast media* containing *iodine* or *barium* is injected in the ventricles of brain or in subarachnoid space or blood vessels and radiograph is taken. These *contrast radiographs* are as follows:

1. *Myelography* – the contrast media is injected into spinal subarachnoid space.
2. Ventriculography – the contrast media is injected into ventricles of brain
3. Cerebral angiography (carotid or vertebral).

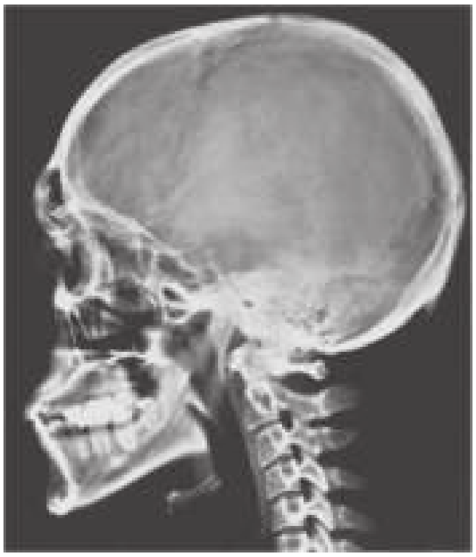


Fig. 15.5: Lateral view of skull and cervical vertebrae

Ultrasonography (USG)

It is noninvasive, painless and a safe imaging technique. *Contrast media* is a substance that is introduced into a part of body (blood vessels or ventricles of brain) to improve the visibility of internal structure during radiography.

Uses:

1. For assessing foetal CNS development
2. For detecting midline shift
3. Doppler effect is useful for assessing blood flow through carotid arteries
4. Postnatally, USG is useful before closure of fontanelle.

Computerised Tomography or CT Scan

It is noninvasive radiographic imaging. It provides more detailed information than plain radiographs. It gives sectional views of brain. These images can be assembled to produce three-dimensional images.

Scale in CT scan: The structures are seen ranging from back, grey to white in colour as follows:

Black colour → air → fat → water → CSF → white matter → grey matter → blood → bone → metal → white colour. Thus, the bones look white, ventricles and CSF look black, and soft tissue has variable shades of grey colour.

Cranial CT scan gives information about size and shape of ventricles of brain, size of brain tissue, injuries, hematoma, calcified tissues, tumours, infarction, abscess, and encephalitis (Fig. 15.6).

Spinal CT scan gives information of intervertebral disc, spinal cord injury, subarachnoid space (with injection of contrast media).

Magnetic Resonance Imaging (MRI)

In MRI, the body is exposed to high energy magnetic field and using radiowaves, the sectional images are captured. MRI gives higher details of soft tissues and less hazardous than CT scan (Fig. 15.7). It provides good contrast between grey and white matters. MRI takes 30 to 40 minutes for imaging whereas CT scan takes only 5 minutes. MRI cannot be done in patients with artificial joints, eye implants, intrauterine devices and pacemakers.

MRI is useful in detection of tumours of brain, developmental anomalies, vascular aneurysm, stroke, trauma, disease of pituitary gland, multiple sclerosis, and so on.

Positron Emission Tomography (PET)

In the PET scan, radioactively labeled, metabolically active chemical is injected in bloodstream. Then, the emission of *positron-emitting radioactive isotopes* is measured and images of brain created. Based on the tissue activity, the images show (Fig. 15.8): Black – rainbow colours – red colour.

Black or darkest violet indicates absence of activity and red indicates very high activity. The PET scan is useful in detection of *cancers*. It is useful in detection

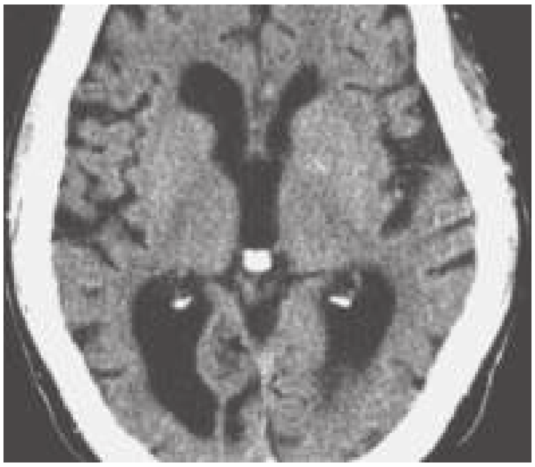


Fig. 15.6: Computerised tomography (CT) scan

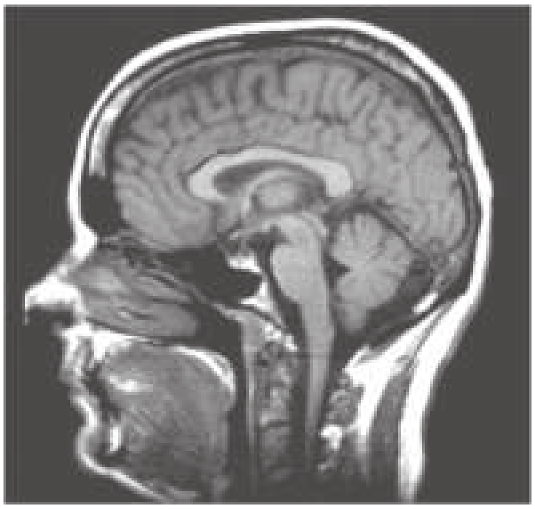


Fig. 15.7: Magnetic resonance imaging (MRI)

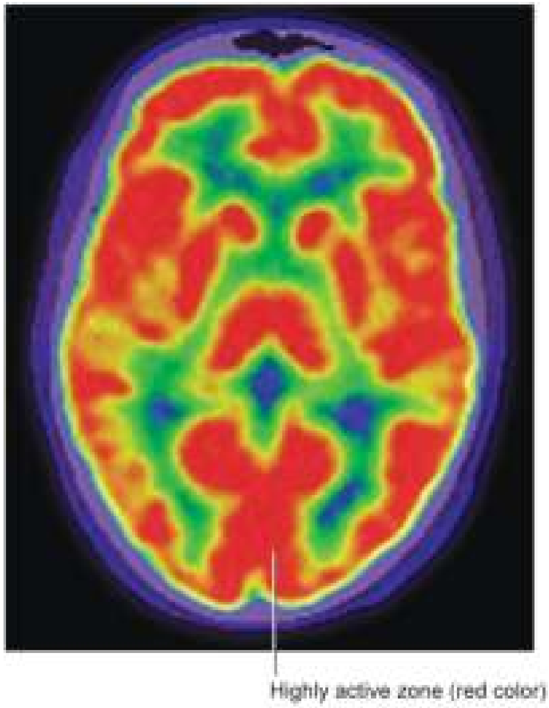


Fig. 15.8: Positron emission tomography (PET) scan (*Image courtesy*: Dr Abhijeet Taori)

of blood flow, oxygen and glucose metabolism, brain activity, dementia/Alzheimer's disease, and ischemic areas.

Single Photon Emission Computed Tomography (SPECT)

It uses *gamma-ray-emitting radioisotopes*. It is useful for *epilepsy* cases. The radioactive tracer is injected at the time of seizure, and it is taken-up by the active regions of the brain. The taken-up tracer does not distribute. Hence, scan is done after termination of seizure. SPECT measures blood flow to the brain (Fig. 15.9).

Note: The CT scan is useful for detection of calcified pineal gland and also for detection of dilated ventricle of brain in case of hydrocephalus (Figs 15.10 and 15.11).

Cerebral Angiography

Cerebral angiography is a radiological technique by which cerebral vessels can be visualised. The arterial system is visualised by carotid angiography (Fig. 15.12), and the vertebral system by vertebral angiography (Fig. 15.13).

Dye: About 10 to 12 ml of 30% pyelocil or diodone.

Technique: For carotid angiography, the common carotid artery is located at the carotid tubercle and the dye is injected percutaneously. A series of skiagrams are taken rapidly at intervals of 1 second. Within 2 seconds after the commencement of injection, the dye reaches the cerebral arteries, and after 2 seconds it is in the veins. After another two seconds or so, the dye passes into the intracranial venous sinuses. The skiagrams taken at different intervals provide arteriograms, venograms (or phlebograms) and sinograms.

Similarly for vertebral angiography, the dye is injected into the vertebral artery and skiagrams are taken as described above.

Indications: Cerebral angiography is helpful in diagnosis of intracranial tumours, haematomas, aneurysms and angiomas.

MR angiography: This technique employs modification so that blood vessels can be visualised without injecting the dye. The conventional angiography is still preferred.

Digital subtraction angiography (DSA): In this procedure, low concentrations of contrast media are used. Bones and

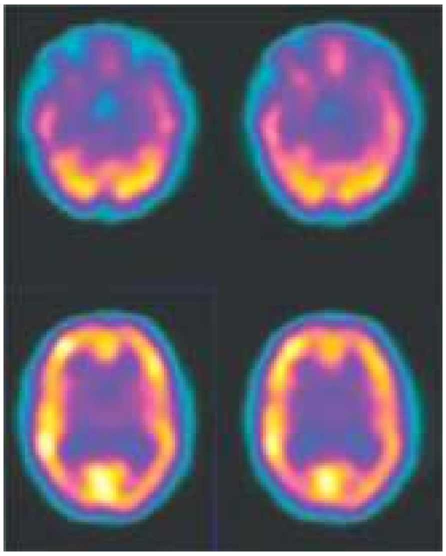


Fig. 15.9: Single photon emission computed tomography (SPECT) scan (*Image courtesy*: Dr Abhijeet Taori)

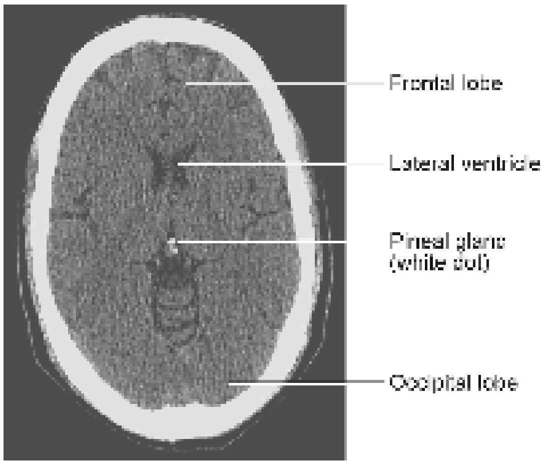


Fig. 15.10: Calcified pineal gland (due to aging) on CT scan (*Image courtesy*: Dr Abhijeet Taori)

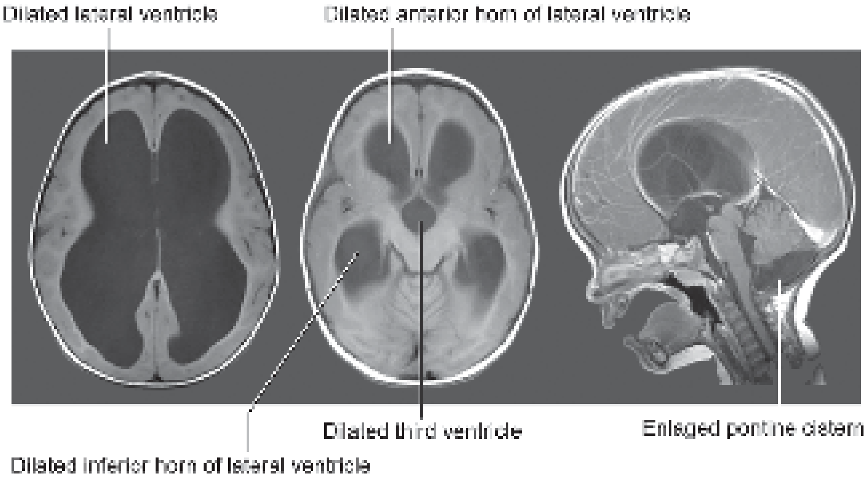

Dilated lateral ventricle
Dilated anterior horn of lateral ventricle
Dilated third ventricle
Enlarged pontine cistern
Dilated inferior horn of lateral ventricle

Fig. 15.11: Dilated ventricles (hydrocephalus) on CT scan (*Image courtesy*: Dr Abhijeet Taori)

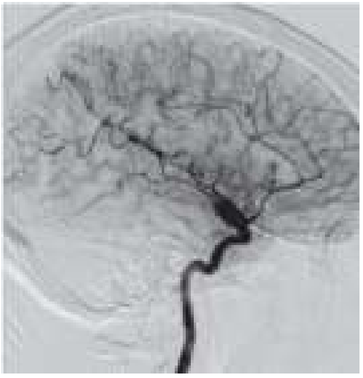


Fig. 15.12: Carotid angiography

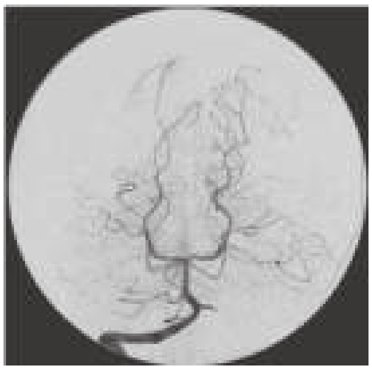


Fig. 15.13: Vertebral angiogram

muscles are removed with the help of the computer. Ideal method is arterial DSA wherein diluted contrast medium is injected into the artery to see its course, branches and their diseases.

Because of these modern and safe procedures, the older techniques—pneumoencephalography, ventriculography and myelography—have become obsolete.

Electrophysiological Methods

a. *Electromyography (EMG):* This is the study of electrical activity accompanying the muscle contraction. It is also used to study the action of various muscles.

b. *Electroencephalography (EEG):* The pattern of electrical activity of brain is analysed by putting electrodes in the scalp at different points and recording it in the machine.

c. *Nerve conduction studies* done to estimate the rate of conduction through the nerve fibres.

These procedures may be used according to the requirement of the patient.

BDC's Anatomy e-book

1. Evolution of the head
2. Further reading

Chapter 16

Autonomic Nervous System

Autonomic nervous system comprises sympathetic and parasympathetic components. It is also called *visceral nervous system* (Figs 16.1a and b).

Sympathetic system is active during fright, flight or fight. During any of these activities, the pupils dilate, skin gets pale, blood pressure rises, blood vessels of skeletal muscles, heart, lungs and brain dilate. There is hardly any activity in the digestive tract due to which the individual does not feel hungry. The person is tense and gets tired soon. This is the larger of the two components of autonomic nervous system.

Parasympathetic system has the opposite effects of sympathetic system. This component is sympathetic (kind) to the digestive tract. In its activity, digestion and metabolism of food occurs. Heart beats normally. Person is relaxed and can do creative work.

Autonomic nervous system is controlled by brainstem and cerebral hemispheres. These include reticular formation of brainstem, thalamic and hypothalamic nuclei, limbic lobe and prefrontal cortex including the ascending and descending tracts interconnecting these regions.

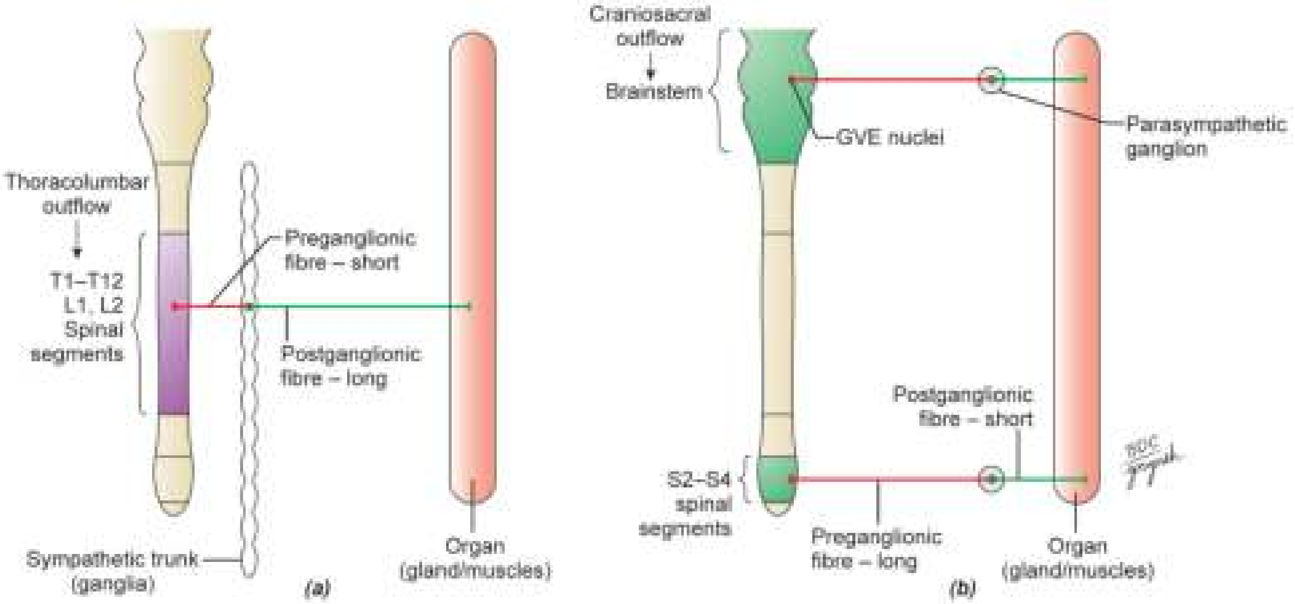
Comparison of parasympathetic and sympathetic nervous systems is given in Table 16.1.

SYMPATHETIC NERVOUS SYSTEM: THORACOLUMBAR OUTFLOW

It consists of two ganglionated trunks, their branches, prevertebral ganglia, and plexuses. It supplies all the viscera of thorax, abdomen and pelvis, including the blood vessels of head and neck, brain, limbs, skin and the sweat glands as well as arrector pilorum muscle of skin.

The preganglionic fibres are axons of neurons situated in the lateral horns of T1–L2 segments of spinal cord. They leave spinal cord through their respective ventral roots, to reach sympathetic ganglia and beginning of ventral rami via white rami communicantes (wrc) [singular: ramus communicans]. There are 14 wrc on each side. These fibres can have following alternative routes (Fig. 16.2):

- They relay in the ganglion of the sympathetic trunk, postganglionic fibres pass via the grey rami


Thoracolumbar outflow
T1–T12
L1, L2
Spinal
segments
Preganglionic fibre – short
Postganglionic fibre – long
Sympathetic trunk (ganglia)
Organ (gland/muscles)
(a)
Craniosacral outflow
Brainstem
GVE nuclei
Parasympathetic ganglion
Postganglionic fibre – short
S2–S4 spinal segments
Preganglionic fibre – long
Organ (gland/muscles)
(b)

Figs 16.1a and b: (a) Sympathetic nervous system and (b) parasympathetic nervous system (GVE: General visceral efferent)

TABLE 16.1: Comparison of parasympathetic and sympathetic nervous systems

	Parasympathetic	*Sympathetic*
Outflow	Craniosacral outflow	Thoracolumbar outflow
Preganglionic neuron	Located in midbrain, pons and medulla oblongata and pass through III, VII, IX, X cranial nerves and also along S2–S4 segments of spinal cord	Located in lateral horn of spinal cord from T1–T12 and L1–L2 segments
Preganglionic fibres	Longer (Fig. 13.3b), myelinated	Shorter (Fig. 13.3a), myelinated
Relay of impulses	Occurs in neurons close to viscera	Occurs in neurons little away from the viscera they supply
Postganglionic fibres	Short, nonmyelinated	Long, nonmyelinated
Neurotransmitter	Both at preganglionic endings and postganglionic endings, acetylcholine is released	At preganglionic endings, acetylcholine is released. At postganglionic endings, adrenaline is released, except in cases of sweat glands where acetylcholine is released
Number of synapses	Preganglionic neuron makes synapses with much smaller number of neurons. Impulses are localised	Preganglionic neuron makes connection with large number of postganglionic nerve cells and impulses are widespread
Postganglionic supply	Only the viscera are supplied by postganglionic fibres. These do not supply blood vessels of skeletal muscles	All the viscera are supplied by post-ganglionic fibres. The only exception is suprarenal gland which is supplied by the preganglionic fibres
Functions	These activities are discrete as well as isolated and conserve the body energies	These activities are mass reactions, widely diffuse in their action. These reactions are catabolic in nature and are used in fright, flight or fight
Action of skin	Nil	Sudomotor, pilomotor and vasomotor
Effect on blood vessels	Blood vessels to the glands of gastrointestinal tract are dilated	Blood vessels to skeletal muscles (cholinergic), heart and brain are dilated
Effect of gastrointestinal system	Secretory to the glands, motor to the smooth muscles and inhibitory to the sphincters of gut	Decreases the secretory activity of glands, including the peristalsis of gut. It is motor to the sphincters
Effect on pupil	Pupil is constricted, lens curvature is increased as in reading	Dilates the pupil
Heart	Slows the pulse, maintains normal blood pressure	Tachycardia, rise in blood pressure. Dilates the coronaries
Lungs	Increase the secretions of glands of lungs and is bronchoconstrictor	Decrease the secretions, is bronchodilator. Adrenaline-like drugs are given in asthma
Urinary bladder	Both filling and emptying of urinary bladder are controlled by parasympathetic system	Supplies only blood vessels of bladder, sphincter vesicae is contracted by sympathetic action during ejaculation
Erectile tissue	Relaxes, causes erection	—
Action	Conserves energy	Prepares for emergency

communicantes (grc) and get distributed to the blood vessels of skin, sweat glands and to arrector pili muscles.

- These may pass through the corresponding ganglion and ascend to a ganglion higher before terminating in the above manner.
- These may pass through the corresponding ganglia and descend to a ganglion lower and then terminate in the above manner.
- Postganglionic fibres from upper thoracic ganglia supply the thoracic viscera.
- Some preganglionic fibres pass to corresponding ganglia and emerge from these (unrelayed) in the form of splanchnic nerves to supply the abdominal and pelvic viscera after synapsing in the ganglia situated in the abdominal cavity.
- A few fibres of splanchnic nerves reach the medulla of the suprarenal gland.

Sympathetic trunks on either side of the body extend from cervical region to the coccygeal region where both trunks fuse to form a single *ganglion impar.* Sympathetic trunk has cervical, thoracic, lumbar, sacral and coccygeal parts. The branches of each part are discussed below.

Cervical Part

It extends from base of skull to the neck of 1st rib. It has three ganglia—superior, middle and inferior cervical ganglia. Branches of these ganglia are tabulated in Table 16.2.

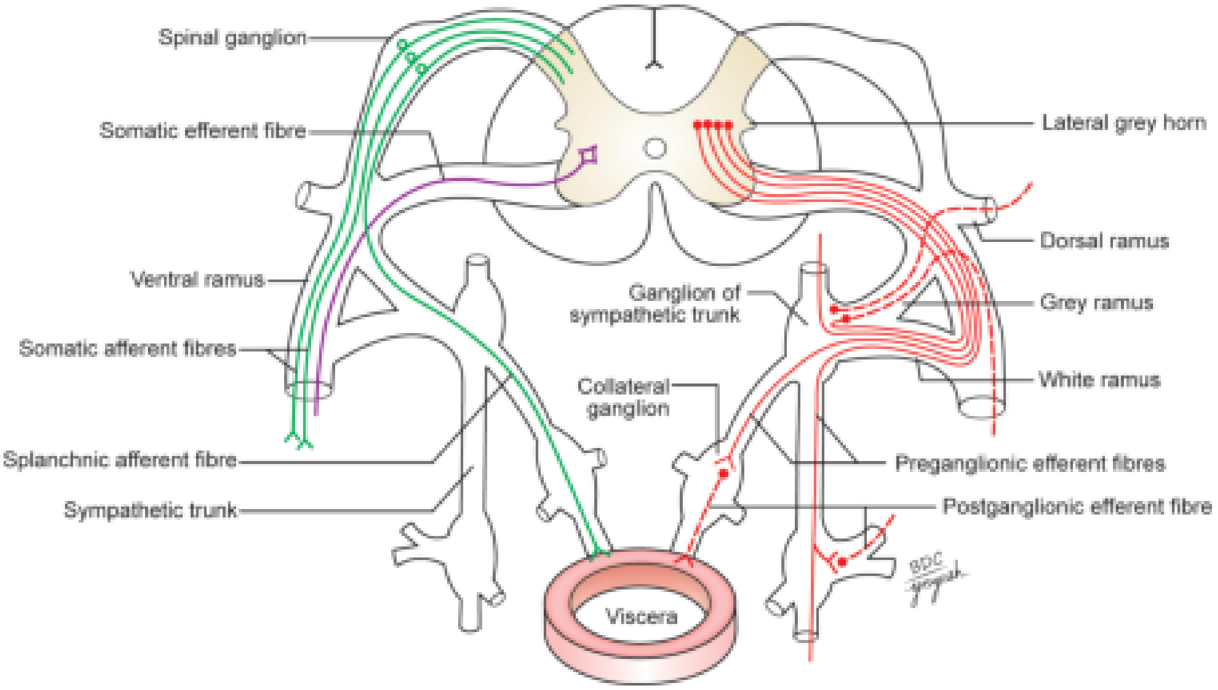

Spinal ganglion
Somatic efferent fibre
Ventral ramus
Somatic afferent fibres
Splanchnic afferent fibre
Sympathetic trunk
Ganglion of sympathetic trunk
Collateral ganglion
Viscera
Lateral grey horn
Dorsal ramus
Grey ramus
White ramus
Preganglionic efferent fibres
Postganglionic efferent fibre
BDC

Fig. 16.2: Components of a typical spinal nerve

TABLE 16.2: Branches of superior, middle and inferior cervical ganglia

	Superior cervical ganglion	*Middle cervical ganglion*	*Inferior cervical ganglion*
Arterial branches	i. Along internal carotid artery as internal carotid nerve ii. Along common carotid and external carotid arteries	Along inferior thyroid artery —	Along subclavian and vertebral arteries —
Grey rami communicantes	Along cervical 1–4 nerves	Along 5 and 6 cervical nerves	Along 7 and 8 cervical nerves
Along cranial nerves	Along IX, X, XI, XII cranial nerves	—	—
Visceral branches	Pharynx, thyroid, cardiac	Cardiac	Cardiac

Thoracic Part

There are usually 11 ganglia on the sympathetic trunk of thoracic part. 1st ganglion lies on neck of 1st rib and is usually fused with inferior cervical ganglion and forms stellate ganglion. The lower ones lie on the head of the ribs. The sympathetic trunk continues with its abdominal part by passing behind the medial arcuate ligament.

The ganglia are connected with the respective spinal nerves via the white ramus communicans (from the spinal nerve to the ganglion) and the grey ramus communicans (from the ganglion to the spinal nerve, i.e. ganglion gives grey (ggg)).

Branches

1. Grey rami communicantes to all the spinal nerves of thorax, i.e. T1–T12. The postganglionic fibres pass along the spinal nerves to supply cutaneous blood vessels, sweat glands and arrector pili muscles.
2. White rami communicantes from upper 4–6 ganglia travel up the cervical part of sympathetic trunk to relay in the three cervical ganglia. Fibres from the lower thoracic ganglia T10–L2 pass down as preganglionic fibres to relay in the lumbar or sacral ganglia.
3. Second to fifth ganglia give postganglionic fibres to heart, lungs, aorta and oesophagus.
4. Lower eight ganglia give fibres which are preganglionic (unrelayed) for the supply of abdominal viscera. These are called splanchnic (visceral) nerves (*see* BD Chaurasia's Human Anatomy Vol 1, Fig. 14.15).
   - Ganglia T5–T9 give fibres which constitute greater splanchnic nerve.
   - Ganglia T10–T12 give fibres that constitute lesser splanchnic nerve.
   - Ganglia L1–L2 give fibres that constitute lowest splanchnic nerve.

Abdominal/Lumbar Part

It runs along the medial border of psoas major muscle. It is continuous with the pelvic part by passing behind the common iliac vessels. There are four ganglia in the lumbar or abdominal part. Only upper two ganglia receive white ramus communicans from the ventral primary rami of first and second lumbar nerves.

Branches

1. Grey rami communicantes to the L1–L5 spinal nerves. These pass along the spinal nerves to be distributed

to the sweat glands, cutaneous blood vessels and arrector pili muscles (sudomotor, vasomotor and pilomotor).

2. Postganglionic fibres pass medially to the aortic plexus.
3. Postganglionic fibres pass in front of common iliac vessels to form hypogastric plexus, which is also supplemented by branches of aortic plexus.

Aortic plexus: This plexus is formed by preganglionic sympathetic, postganglionic sympathetic, preganglionic parasympathetic and visceral afferent fibres around the abdominal aorta. This plexus is concentrated around the origin of ventral and lateral branches of abdominal aorta. These are known as coeliac plexus, superior mesenteric plexus, inferior mesenteric plexus and renal plexus.

Pelvic/Sacral and Coccygeal Parts of Sympathetic Trunk

Pelvic part runs in front of sacrum, medial to ventral sacral foramina. Caudally, the two trunks unite and fuse into a single ganglion impar in front of coccyx. There are four ganglia in this part of sympathetic trunk. Their branches are:

1. Grey rami communicantes to the sacral and coccygeal nerves.
2. Branches to the pelvic plexuses.

Collateral/Prevertebral Ganglia and Plexuses

Coeliac plexus is the largest of the three autonomic plexuses, coeliac, superior mesenteric and inferior mesenteric plexuses. It is a dense network of nerve fibres which unite the two coeliac ganglia. The ganglia receive the greater splanchnic nerves, lesser splanchnic nerves of both sides including some filaments of vagi and phrenic nerves.

Coeliac ganglia are two irregularly shaped ganglia. Each ganglion receives greater splanchnic nerve. The lower part of the ganglion receives lesser splanchnic nerve and is also called aorticorenal ganglion. The aorticorenal ganglion gives off the renal plexus which accompanies the renal vessels.

Secondary plexuses arising from coeliac and aorticorenal plexus are distributed along the branches of the aorta, namely phrenic, splenic, left gastric, hepatic, intermesenteric, suprarenal, renal, gonadal, superior and inferior mesenteric plexuses.

Superior Hypogastric Plexus

This plexus lies between the two common iliac arteries and is formed by: (i) aortic plexus, and (ii) branches from lumbar sympathetic ganglia. It divides into right and left inferior hypogastric plexuses (pelvic plexus); which runs on the medial side of internal iliac artery and is supplemented by pelvic splanchnic nerves (parasympathetic nerves). Thus, inferior hypogastric plexus contains both sympathetic and parasympathetic nerves. These are for the supply of the pelvic viscera along the branches of the arteries.

PARASYMPATHETIC NERVOUS SYSTEM

Craniosacral Outflow

Preganglionic parasympathetic fibres are present in four cranial nerves, e.g. III, VII, IX, and X cranial nerves and also along S2–S4 spinal nerves. Four ganglia namely ciliary, pterygopalatine, submandibular and otic, are concerned with efferent parasympathetic fibres of III, VII and IX nerves.

1. Oculomotor parasympathetic fibres arise in midbrain, from the Edinger-Westphal nucleus. Preganglionic fibres pass through the III nerve and leave as motor root along the nerve to inferior oblique muscle to enter the *ciliary ganglion*. These fibres are relayed in the ciliary ganglion, and the postganglionic fibres pass via the short ciliary nerves to be distributed to ciliaris and sphincter pupillae muscles.
2. Facial nerve contains efferent parasympathetic fibres. These are the axons of neurons of superior salivatory nucleus. These fibres leave the brain as nervus intermedius, and form part of the facial nerve and pass along its chorda tympani branch. Chorda tympani nerve joins the lingual nerve in the infratemporal fossa. These fibres travel with the lingual nerve to reach submandibular ganglion. Fibres of chorda tympani nerve relay in this ganglion from where postganglionic fibres supply the submandibular and sublingual salivary glands.

   Greater petrosal branch of facial nerve joins the deep petrosal (sympathetic fibres) to form the *nerve of pterygoid canal*. Only greater petrosal nerve fibres relay in the *pterygopalatine ganglion*. These postganglionic fibres supply lacrimal gland, glands of nose, pharynx and palate.
3. Glossopharyngeal nerve contains the axons of the inferior salivatory nucleus. They travel through IX nerve and are given off in its tympanic branch which forms tympanic plexus from where the lesser petrosal nerve starts. The lesser petrosal nerve relays in the otic ganglion. The postganglionic fibres are given to the auriculotemporal nerve to reach the parotid salivary gland.
4. Vagus or X cranial nerve contains efferent parasympathetic fibres. They have their origin in the dorsal nucleus of vagus and pass along its pulmonary, cardiac, oesophageal, gastric and intestinal branches.

Sacral Outflow

Pelvic Splanchnic Nerves

These are the preganglionic fibres constituting the sacral component of the craniosacral outflow of the parasympathetic nervous system. These arise from lateral horn cell of S2–S4 segments of spinal cord. The axons of these neurons pass along the ventral rami of S2–S4 nerves to join the inferior hypogastric plexus to be distributed to the pelvic viscera.

Some of the parasympathetic fibres ascend from inferior hypogastric plexus to reach superior hypogastric plexus and finally the inferior mesenteric plexus. Thereafter, these fibres are distributed along the branches of inferior mesenteric artery to supply left one-third of transverse colon, descending colon and pelvic colon. These preganglionic fibres relay in the neurons situated in the wall of the viscera.

Efferent Pathways of Cranial Part of Parasympathetic Nervous System

Preganglionic parasympathetic fibres are present in four cranial nerves, e.g. cranial nerves III, VII, IX, X and along spinal nerves S2–S4. Four ganglia, namely ciliary, pterygopalatine, submandibular and otic, are concerned with efferent parasympathetic fibres.

NERVE SUPPLY OF THE VISCERA

See BD Chaurasia's Human Anatomy Vol 1, Fig. 14.15.

Heart

Preganglionic sympathetic neurons are located in lateral horns T1–T5 segments of spinal cord. These fibres pass along the respective ventral roots of thoracic nerves to synapse with the respective ganglia of the sympathetic trunk. After relay, the postganglionic fibres form thoracic branches which intermingle with the vagal fibres, to form cardiac plexus.

Some fibres from T1–T5 segments of spinal cord reach their respective ganglia. These fibres then travel up the cervical part of the sympathetic chain and relay in superior, middle and inferior cervical ganglia. After relay, the postganglionic fibres form the three cervical cardiac nerves. Preganglionic parasympathetic neurons for the supply of heart are situated in the dorsal nucleus of vagus nerve.

Sympathetic activity increases the heart rate. Larger branches of coronary arteries are mainly supplied by sympathetic nerves. It causes vasodilation of coronary arteries. Impulses of pain travel along sympathetic fibres. These fibres pass through sympathetic trunk and reach the spinal cord via T1–T5 spinal nerves. Thus, the pain may be referred to the area of skin supplied by T1–T5 nerves, i.e. retrosternal and medial side of the left upper limb. Since one is more conscious of impulses coming from skin than the viscera, one feels as if the pain is in the skin. This is the basis of the referred pain.

Smaller branches of coronary arteries are supplied by parasympathetic nerves. These nerves are concerned with slowing of the cardiac cycle. The nerves reach the heart by two plexuses—superficial and deep cardiac.

Superficial Cardiac Plexus

- Superior cervical cardiac branch of left sympathetic trunk.
- Inferior cervical cardiac branch of left vagus nerve.

Deep Cardiac Plexus

It consists of two halves which are interconnected and lie anterior to bifurcation of trachea.

Right half	*Left half*
Superior, middle, and inferior cervical cardiac branches of right sympathetic trunk	Only middle and inferior branches of left sympathetic trunk
Cardiac branches of T2–T4 ganglia of right side	Same
Three cervical cardiac branches of right vagus	Two cervical cardiac branches of left vagus
Two branches of right recurrent laryngeal nerve arising from neck region	Same, but coming from thoracic region

Branches from the plexus give extensive branches to pulmonary and right and left coronary plexuses. Branches from the coronary plexuses supply both the atria and the ventricles. Left ventricle receives richer nerve supply because of its larger size.

Lungs

The lungs are supplied from the anterior and posterior pulmonary plexuses. The anterior plexus is an extension of deep cardiac plexus. The posterior plexus is formed from branches of vagus and T2–T5 sympathetic ganglia. Small ganglia are found on these nerves for the relay of parasympathetic (brought via vagus nerve) fibres. Parasympathetic system is bronchoconstrictor (motor) whereas sympathetic system is inhibitory. Sympathetic stimulation causes relaxation of smooth muscles of bronchial tubes (bronchodilator). The pressure of inspired air also causes bronchodilation.

Gastrointestinal Tract

Oesophagus

- Cervical part of oesophagus receives branches from recurrent laryngeal nerve and middle cervical ganglion of sympathetic trunk.
- Thoracic part gets branches from vagal trunks and oesophageal plexus as well as from sympathetic trunks and greater splanchnic nerves.
- Abdominal part receives fibres from vagal trunks (i.e. anterior and posterior gastric nerves), thoracic part of sympathetic trunks, greater splanchnic nerves and plexus around left gastric artery. The nerves form a plexus called myenteric plexus between two layers of the muscularis externa and another one in the submucous layer.

Stomach

Sympathetic supply reaches from coeliac plexus along gastric and gastroepiploic arteries. A few branches also reach from thoracic and lumbar sympathetic trunks. Parasympathetic supply is derived from vagus nerves. The left vagus forms anterior gastric, while right vagus comprises posterior gastric nerve. The anterior gastric nerve supplies cardiac orifice, anterior surface of body as well as fundus of stomach and pylorus.

Posterior gastric nerve supplies posterior surface of body and fundus till pyloric antrum. It gives number of coeliac branches which form part of the coeliac plexus.

Vagus is secretomotor to stomach. Its stimulation causes secretion which is rich in pepsin. Sympathetic system inhibits peristalsis and is motor to the pyloric sphincter. It also carries pain fibres from stomach.

Small Intestine

The nerves of this part of the gut are derived from coeliac ganglia formed by posterior gastric nerve (vagus) and splanchnic nerves (sympathetic) and the plexus around superior mesenteric artery. These nerves form myenteric plexus and submucous plexus. Parasympathetic fibres relay in the ganglion cells present in these plexuses. Parasympathetic system is secretomotor to the intestines and inhibits the sphincters. Sympathetic system inhibits the peristaltic movements of intestine but stimulates the sphincters. The autonomic nerves in the intestine form enteric nervous system.

Large Intestine

Large intestine, except the lower half of anal canal, is supplied by both components of autonomic nervous system. The derivatives of midgut, i.e. caecum, vermiform appendix, ascending colon and right two-thirds of transverse colon receive their sympathetic nerve supply from coeliac and superior mesenteric ganglia and parasympathetic from vagus nerve.

Left one-third of transverse colon, descending colon, sigmoid colon, rectum and upper half of anal canal (developed from hindgut) receive their sympathetic nerve supply from lumbar part of sympathetic trunk and superior hypogastric plexus through the plexuses on the branches of inferior mesenteric artery. Its effect is chiefly vasomotor. Parasympathetic supply of colon is received from pelvic splanchnic nerves S2–S4. Pelvic splanchnic nerves give fibres to inferior hypogastric plexuses to supply rectum and upper half of anal canal. Some of inferior hypogastric plexuses pass up through superior hypogastric plexus and get distributed along the branches of inferior mesenteric artery to the left third of transverse colon, descending and sigmoid colons.

Rectum and Anal Canal

Sympathetic fibres pass along inferior mesenteric and superior rectal arteries and also via superior and inferior hypogastric plexuses.

Parasympathetic supply is from pelvic splanchnic nerves, which join inferior hypogastric plexus. This supply is motor to muscles of rectum and inhibitory to internal sphincter.

The external anal sphincter is supplied by inferior rectal branch of pudendal nerve. Afferent impulses of physiological distension of rectum and sigmoid colon are carried by parasympathetic nerves, whereas pain impulses are conveyed both by the sympathetic and parasympathetic nerves.

Pancreas

Branches of coeliac plexus pass along the arteries. Effect of sympathetic nerve is vasomotor. The nerve fibres make synaptic contact with acinar cells before innervating the islets. The parasympathetic ganglia lie in sparse connective tissue of the gland and the islet cells.

Liver

Nerves of the liver are derived from hepatic plexus which is an offshoot of coeliac plexus. This contains both sympathetic and parasympathetic fibres. These accompany the blood vessels and bile duct. Both types of nerve fibres also reach the liver through various peritoneal folds.

Gallbladder

Parasympathetic and sympathetic nerves of gallbladder are derived from coeliac plexus, along the hepatic artery (hepatic plexus) and its branches. Fibres from the right phrenic nerve (C4) through the communication of coeliac and phrenic plexuses also reach gallbladder in the hepatic plexus. Thus, the reason of pain in the right shoulder (from where impulses are carried by lateral supraclavicular nerve C4) in cholecystitis is the stimulation of phrenic nerve fibres (C4) due to the communication between phrenic plexus and hepatic plexus via coeliac plexus. Coeliac plexus gets fibres from thoracic 7 ganglia. Thoracic 7 nerve supplies skin over inferior angle of scapula. Hepatic plexus, an offshoot of coeliac plexus, supplies gallbladder. So pain of gallbladder is also referred to inferior angle of right scapula.

Urinary System

The kidneys are supplied by renal plexus formed from coeliac ganglion, coeliac plexus, lowest thoracic splanchnic nerve, and first lumbar splanchnic nerve. The plexus runs along the branches of renal artery to supply the vessels, renal glomeruli and tubules. These are chiefly vasomotor in function.

Ureter is supplied in its upper part from renal and aortic plexus, middle part from superior hypogastric plexus and lower part from hypogastric nerve and inferior hypogastric plexus.

Vesical Plexus

Sympathetic fibres arise from T11–T12 segments and L1–L2 segments of spinal cord. Parasympathetic fibres arise from S2–S4 segments of spinal cord, which relay in the neurons present in and near the wall of urinary bladder. Parasympathetic system is motor to the muscular coat and inhibitory to the sphincter; sympathetic system is chiefly vasomotor. Emptying and filling of urinary bladder is normally controlled by parasympathetic system only.

Male Reproductive Organs

Testicular plexus accompanies the testicular artery to reach the testis. It is formed by renal and aortic plexus, and also from superior and inferior hypogastric plexuses. This plexus supplies the epididymis and ductus deferens.

Prostatic plexus is formed from inferior hypogastric plexus and branches are distributed to prostate, seminal vesicle, prostatic urethra, ejaculatory ducts, erectile tissue of penis, penile part of urethra and bulbourethral glands. Sympathetic nerves cause vasoconstriction, and parasympathetic nerves cause vasodilatation.

Comparison of parasympathetic and sympathetic nervous systems is tabulated in *see* Table 16.1.

Female Reproductive Organs

The ovary and uterine tube receive their nerve supply from plexus around the ovarian vessels. This plexus is derived from renal, aortic plexuses and also from superior and inferior hypogastric plexuses. Sympathetic fibres derived from T10–T11 segments of spinal cord are vasomotor in nature whereas parasympathetic fibres are probably vasodilator in function.

Uterus

It is supplied by uterovaginal plexus, formed from the inferior hypogastric plexus. The sympathetic fibres are derived from T12 to L1 segments of spinal cord. Parasympathetic fibres arise from S2–S4 segments of spinal cord. Sympathetic system causes uterine contraction and vasoconstriction, while parasympathetic nerves produce vasodilatation and uterine inhibition. Vagina is supplied by nerves arising from inferior hypogastric plexus to uterovaginal plexus. These supply wall of vagina including vestibular glands and clitoris. Parasympathetic fibres cause vasodilator effect on the erectile tissue.

AFFERENT AUTONOMIC FIBRES

Autonomic afferents are peripheral processes of pseudounipolar cells in some cranial and spinal nerve ganglia. The terminals of autonomic nerves may be loops, rings, tendril-like endings, a few encapsulated ones in the walls of viscera. Viscera are sensitive to stretch, ischaemia and distension. These sensations cause pain and reach up to the level of consciousness.

General visceral afferent fibres are in III, VII, IX, X cranial nerves, S2–S4 nerves and in T1–L2 spinal nerves.

Vagus nerves has a large general visceral afferent component. The superior ganglion is somatic and inferior ganglion is visceral in nature. Their central processes end in dorsal nucleus of vagus or tractus solitarius. Afferents are reached from pharynx and oesophagus via IX, X cranial nerves which are concerned with swallowing reflexes. In the thorax, afferent fibres arise from walls of great vessels, aortic and carotid bodies and bronchial musculature (for cough reflex). General visceral afferent fibres from stomach and intestine also terminate in the dorsal nucleus of vagus which may be responsible for nausea and hunger.

CLINICAL NEUROANATOMY

1. Removal of stellate ganglion improves the blood supply to the upper limb. But its removal causes ***Horner's syndrome*** which is comprised of:
   - Anhidrosis of the same side of face
   - Partial drooping of upper eyelid, i.e. ptosis
   - Enophthalmos
   - Constriction of the pupil
   - Loss of ciliospinal reflex
   - Flushing of face
2. Arteries of the upper limb are innervated by sympathetic fibres. Preganglionic fibres originate from the cell bodies of T2–T5 spinal segments. Fibres ascend in the sympathetic trunk and synapse with middle and inferior cervical ganglia. Postganglionic fibres join the nerves which constitute the brachial plexus, get distributed to the arteries of the upper limb in each region. These fibres may be cut to relieve the symptoms of ***Raynaud's disease***.
3. T2–T5 ganglia and stellate ganglia may be removed in cases of intractable angina pectoris.
4. Arteries of lower limb are supplied by lower three thoracic and upper two lumbar segments of the spinal cord. Femoral artery is supplied by sympathetic fibres from femoral and obturator nerves. Posterior tibial artery receives the postganglionic fibres from common peroneal and tibial nerves. ***Buerger's disease*** may be treated by lumbar sympathectomy.
5. ***Megacolon:*** There is absence of ganglion cells and failure of innervation of the smooth muscle layers of pelvic colon.
6. ***Referred pain:*** If the somatic nerves from skin and afferent fibres from viscera enter the same segment of the spinal cord, the phenomenon of referred pain occurs. Visceral pain in the appendix is produced due to either spasm of its muscle, or distension of its lumen. The afferent impulses ascend through the superior mesenteric plexus, lesser splanchnic nerve to reach the spinal cord at T10 level. Impulses from the skin around umbilicus are also carried by T10 segment.

   Brain is more conscious of impulses from skin. So in early case of appendicitis, though there is stimulation of sympathetic fibres of appendix, person thinks the impulses are arising from skin of umbilicus. So pain of early appendicitis is referred to the umbilicus. Later on when parietal peritoneum is inflamed, pain is localised in the right iliac fossa.
7. Pain fibres from the body of the uterus pass with sympathetic nerves through the hypogastric plexus and the lumbar splanchnic nerves to cells on the dorsal roots of the lower thoracic and upper lumbar nerves. Afferents from cervix pass in dorsal roots of upper sacral nerves. Cauterisation of cervix does not cause pain whereas stretch (dilatation) of cervix is painful.

BDC's Anatomy *e*-book

1. Viva voce questions

Chapter 17

Development of Nervous System

Competency:
AN64.2 Describe the development of neural tube, spinal cord, medulla oblongata, pons, midbrain, cerebral hemisphere and cerebellum.

DEVELOPMENT OF BRAIN

NEURAL TUBE

The whole of nervous system develops from ectoderm except the blood vessels and the microglia (neuroglial tissue) (Figs 17.1 and 17.2).

At the beginning of 3rd week of development, the ectodermal germ layer has the shape of a flat disc that is broader in cephalic region than in the caudal region. With the appearance of the notochord and its inductive influence, ectoderm overlying the notochord thickens to form a slipper-shaped plate, called neural plate. Cells of the plate make-up neuroectoderm and with induction, the process of neurulation starts. The plate is located in the mid-dorsal region in front of the primitive pit. Its lateral edges get raised to form the neural folds.

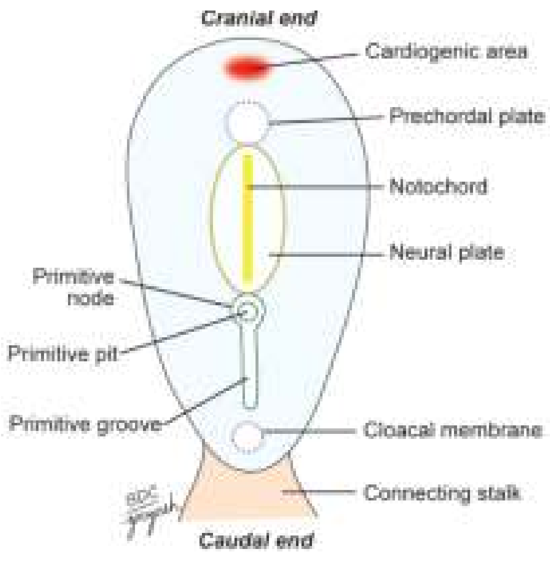

Cranial end
Cardiogenic area
Prechordal plate
Notochord
Neural plate
Primitive node
Primitive pit
Primitive groove
Cloacal membrane
Connecting stalk
Caudal end

Fig. 17.1: Germ disc showing neural plate

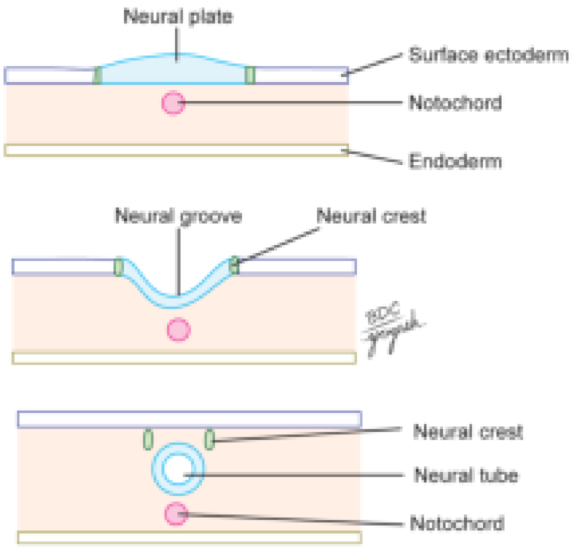

Neural plate
Surface ectoderm
Notochord
Endoderm
Neural groove
Neural crest
Neural crest
Neural tube
Notochord

Fig. 17.2: Formation of neural plate and neural crest

With further development, the neural groove between the two folds on either side becomes deeper. Eventually, the neural folds approach each other in midline and finally fuse, thus forming the neural tube. Fusion begins in the cervical region and proceeds in cephalocaudal direction. At the most cranial and caudal ends of the embryo, fusion is delayed and the cranial and caudal neuropores temporarily form open connections between the base of neural tube and the amniotic cavity.

Final closure of cranial neuropore occurs on 25th day and caudal neuropore two days later of the embryonic life, and eventually neuropores disappear leading to a closed tube.

Before the neural tube is completely closed, it is divisible into an enlarged cranial part with three divisions which forms brain and a caudal tubular part which forms spinal cord.

The cephalic end of the neural tube shows three divisions (Fig. 17.3):

1. Prosencephalon or forebrain
2. Mesencephalon or midbrain
3. Rhombencephalon or hindbrain.

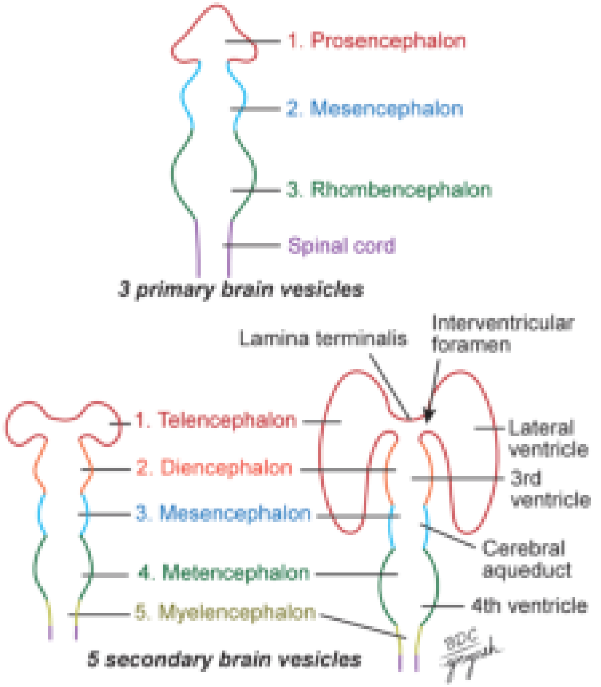

1. Prosencephalon
2. Mesencephalon
3. Rhombencephalon
Spinal cord
3 primary brain vesicles
Lamina terminalis
Interventricular foramen
1. Telencephalon
2. Diencephalon
3. Mesencephalon
4. Metencephalon
5. Myelencephalon
Lateral ventricle
3rd ventricle
Cerebral aqueduct
4th ventricle
5 secondary brain vesicles

Fig. 17.3: Developing brain vesicles

Further Development of the Brain

Prosencephalon, mesencephalon and rhombencephalon are first arranged cephalocaudally. Soon it develops four flexures (Figs 17.4a and b). These are:

a. *Cervical flexure:* It appears at the junction of rhombencephalon and spinal cord.

b. *Cephalic or mesencephalic flexure:* This flexure is located in the region of midbrain.

c. *Rhombencephalic flexure:* The mesencephalon is separated from rhombencephalon by a furrow called rhombencephalic flexure.

d. *Pontine flexure:* When the embryo is 5 weeks old, the prosencephalon consists of two lateral outpocketings—the primitive cerebral hemispheres. At this stage, a deep furrow appears at the middle of rhombencephalon. This is called pontine flexure, and it divides rhombencephalon into metencephalon and myelencephalon.

The flexures change orientation of various parts of brain.

The lumen of the spinal cord, the central canal is continuous with that of primitive brain vesicles.

The cavity of rhombencephalon is known as fourth ventricle, those of cerebral hemisphere are lateral ventricles and cavity of diencephalon is third ventricle.

Cavity of lateral ventricles communicates with that of third ventricle through interventricular foramen of Monro. Cavity of third and fourth ventricles is connected through narrow cerebral aqueduct of Sylvius.

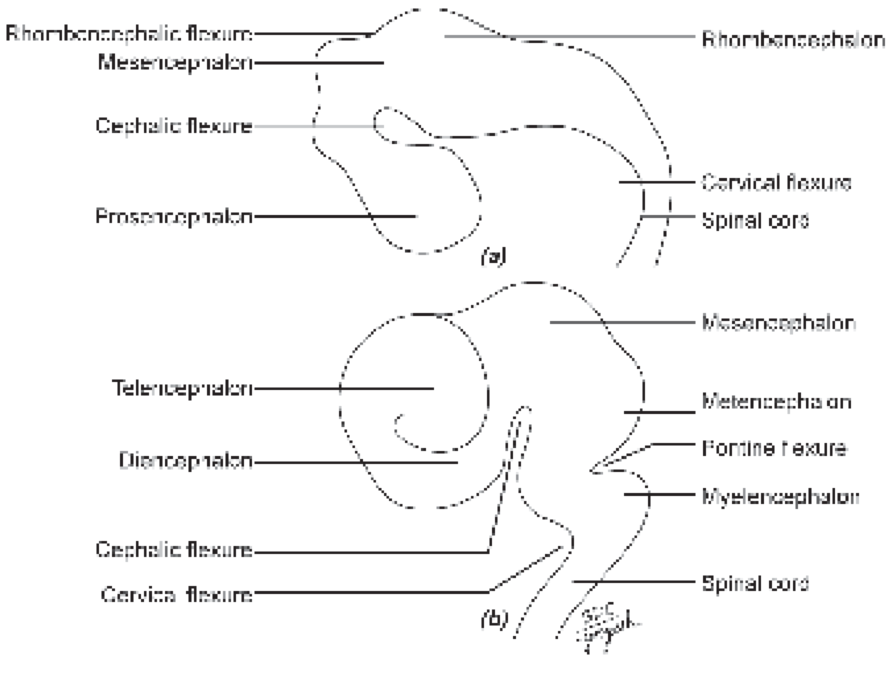
Neural Crest Cells and their Derivatives

During folding of the neural tube, a group of cells are formed along each side of neural groove and after the formation of neural tube, lie between the surface ectoderm and neural tube. These cells (ectodermal in origin) migrate laterally, and are called neural crest cells. They extend from prosencephalon at the cranial end of the tube to the level of caudal somites (Fig. 17.5).

Derivatives of the neural crest cells are as follows:

Dorsal mass of cells

A. Neuroblast cells
  - Dorsal root ganglia
  - Sensory ganglia of V, VII, IX and X cranial nerves
  - Skeletal elements of pharyngeal arches
  - Odontoblast of teeth
  - Parafollicular cells of thyroid gland.


Rhombencephalic flexure
Mesencephalon
Cephalic flexure
Prosencephalon
Rhombencephalon
Cervical flexure
Spinal cord
(a)
Mesencephalon
Telencephalon
Metencephalon
Pontine flexure
Diencephalon
Myelencephalon
Cephalic flexure
Cervical flexure
Spinal cord
(b)

Figs 17.4a and b: Development of the various flexures of the brain

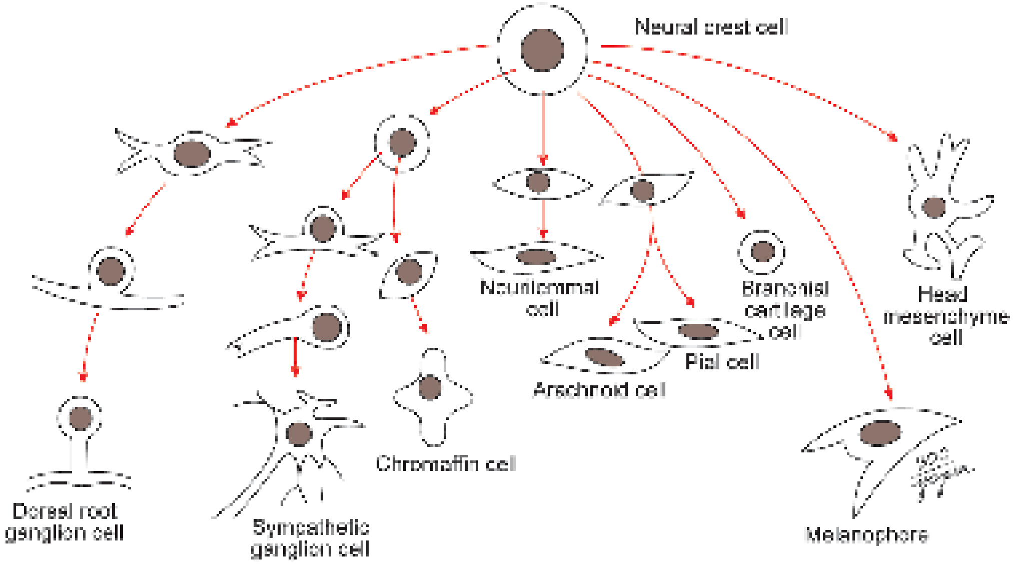


Fig. 17.5: Development of neural crest cells

B. Spongioblast cells
   - Satellite cells in ganglion
   - Schwann cells.

C. Pluripotent cells
   Melanocytes.

Ventral mass

A. Sympatho-chromaffin organ

B. Sympathoblasts
   - Sympathetic ganglionic neurons
   - Parasympathetic ganglionic neurons (ciliary, pterygopalatine, submandibular and otic).

C. Chromaffin cells
   - Chromaffin cells of medulla of adrenal gland
   - Para-aortic body
   - Argentaffin cells in respiratory system
   - Enterochromaffin cells in gut.

Other derivatives

- Facial bones and vault of skull
- Dermis of face and neck
- Muscles of ciliary body
- Sclera and choroids of eyeball
- Substantia propria and posterior epithelium of cornea
- Pharyngeal arch cartilages
- Semilunar valves in heart
- Spiral and bulbar septum in heart.

Diencephalon

The median part of prosencephalon forms diencephalon. It comprises a roof plate and two alar plates. The choroid plexus of third ventricle is formed from ependymal cells of roof plate and the vascular mesenchyme.

After the formation of the telencephalon, the lateral wall of diencephalon becomes thickened and gets divided into three regions, by appearance of two sulci.

These are called epithalamic and hyothalamic sulci, and the central part between the two sulci is called thalamus. The part above the epithalamic groove is a small region represented by habenular nuclei and pineal body. The part below the hypothalamic groove forms hypothalamus.

Pineal body or epiphysis develops from the most caudal part of roof plate. The pineal body initially appears as an epithelial lining in the midline, but by the 7th week of intrauterine life, it begins to evaginate. Eventually, it becomes a solid organ located on the roof of the mesencephalon. It serves as a channel through which light and darkness affect endocrine and behavioural rhythms, i.e. circadian rhythm. In the adult, calcium is frequently deposited in the epiphysis and it even serves as a landmark on an X-ray skull.

As a result of proliferative activity; the various nuclei of thalamus are formed by multiplication of cells in the mantle layer of the wall of diencephalon.

Hypothalamus forming lower portion of the alar plate differentiates into a number of nuclear areas which serve as regulation centre of the visceral functions, i.e. sleep, digestion, body temperature and emotional behaviour.

The prominent group of these nuclei is mammillary body, which forms distinct protuberance on the ventral surface of the hypothalamus on each side of the midline.

Telencephalon

The telencephalon consists of two lateral outpocketings, the cerebral (right and left) hemispheres and a median portion, the lamina terminalis. The cavities of hemispheres, the lateral ventricles, communicate with the lumen of diencephalon, through the interventricular foramen of Monro.

Cerebral Hemispheres

Cerebral hemispheres arise as bilateral (right and left) evaginations at the beginning of 5th week of development from the lateral wall of prosencephalon. By the middle of 2nd month of development, the basal part of hemisphere, i.e. the part which is initially formed by the forward extension of thalamus, begins to increase in size. As a result, this area bulges into the lumen of the lateral ventricle as well as into the foramen of Monro.

In the region where the wall of hemisphere is attached to the roof of diencephalon, the neuroblasts fail to develop and it remains very thin. Here the hemispheric wall consists of a single layer of ependymal cells covered by vascular mesenchyme and together they form choroid plexus. Due to disproportionate growth of various parts of hemisphere, the choroid plexus protrudes into lateral ventricle along a line known as choroid fissure.

Above the choroid fissure, the wall of hemisphere is thickened, thus forming the hippocampus which mainly has an olfactory function and this part bulges into lateral ventricle.

With further growth and expansion, the hemispheres cover the lateral aspect of diencephalon, mesencephalon and cranial portion of metencephalon.

Corpus Striatum

Some of the cells of the mantle layer in thick basal part of lateral wall of hemisphere form corpus striatum. It expands posteriorly and gets divided into two parts:

a. A dorsomedial portion—the caudate nucleus
b. A ventrolateral portion—the lentiform nucleus.

This division occurs by axons passing to and from the cortex of the hemisphere. The fibre bundle thus formed is known as internal capsule (Fig. 17.6).

Lobes of Brain

Continuous growth of cerebral hemispheres in anterior, dorsal, posterior and inferior directions results in formation of frontal, parietal, occipital and temporal lobes. As the growth in the region of corpus striatum slows down, the area between temporal and frontal lobes becomes depressed and forms the insula. The area is later overgrown by adjacent lobes and at the time of birth is almost completely covered. In later part of fetal life due to growth in a limited area, the sulci and gyri make their appearance. This is to accommodate more neurons in a limited area.

Cerebral Cortex

From development point of view, the cerebral cortex consists of:

a. The hippocampal cortex
b. Pyriform cortex
c. The neocortex.

The developing telencephalon has a medial wall, apposed to the counterpart of the opposite side, a superolateral wall and a basal wall. The hippocampal cortex develops in medial wall, pyriform cortex in the marginal layer—superficial to corpus striatum, and neocortex in the superolateral region. Earlier formed cells are neuroblasts. Motor areas of the cortex are rich in pyramidal cells, while the sensory areas have abundance of granular cells (Fig. 17.7).

Cerebral Commissures

In the adult, the right and left halves of the cerebral hemispheres are connected by a number of fibre bundles called commissures, which cross midline.

- The most important is lamina terminalis. It is part of the wall of the neural tube that closes the cranial end of the prosencephalon. After the appearance of telencephalic vesicles, lamina terminalis lies in the anterior wall of third ventricle. Neurons growing from one hemisphere pass to the other through the lamina terminalis. So, it becomes thickened to form commissured plate.
- *Anterior commissure*: The first of the crossing bundles to appear is anterior commissure. It consists of fibres connecting the olfactory bulb and related brain areas of one hemisphere to those of opposite side.
- Hippocampal or fornix commissure is the second to appear.
- *Corpus callosum*: It is the most important commissure. It appears in the 10th week of development and connects non-olfactory areas of the right and left sides.
- *Optic chiasma*: It appears in the anterior wall of diencephalon and contains fibres from medial halves of two retinas.

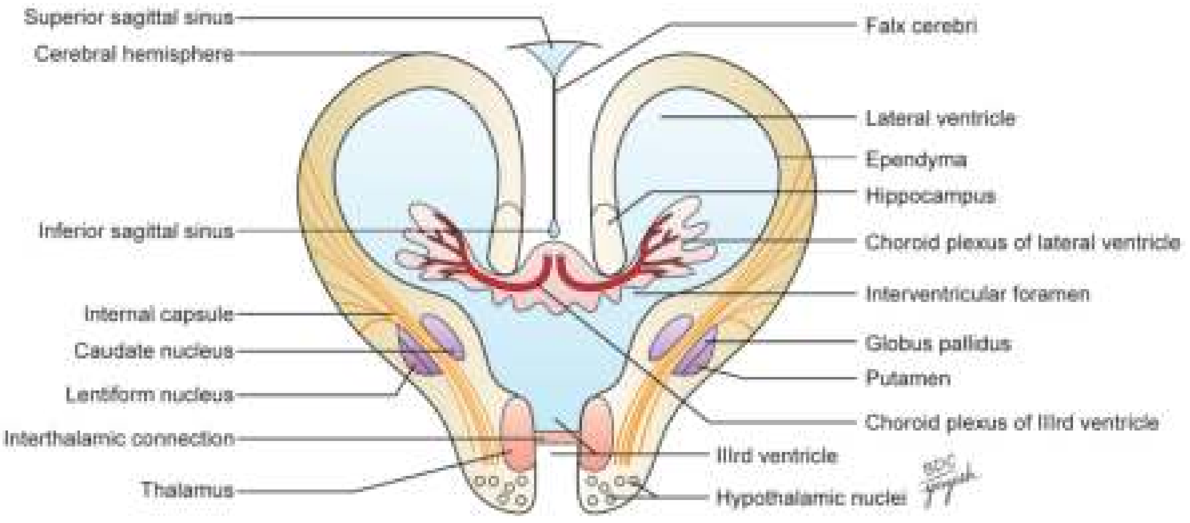


Fig. 17.6: Development of caudate and lentiform nuclei. Between these two nuclei, the fibres of internal capsule are seen

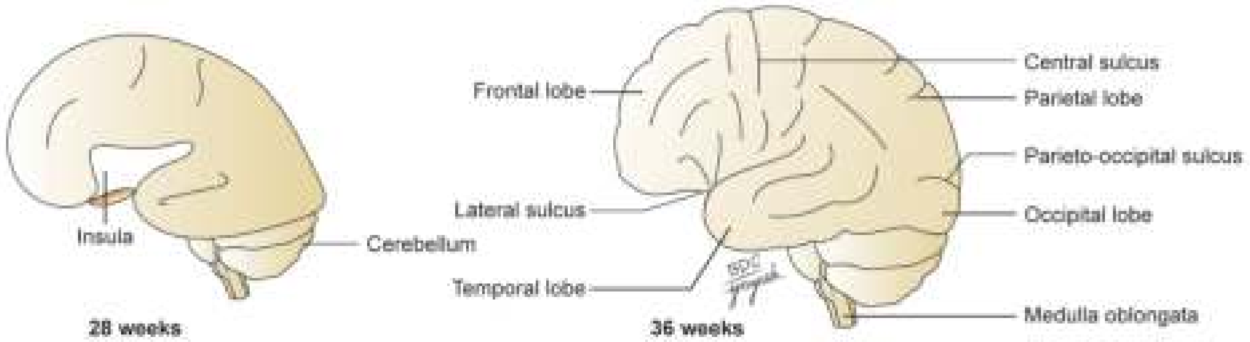

Insula
Cerebellum
28 weeks
Frontal lobe
Lateral sulcus
Temporal lobe
36 weeks
Central sulcus
Parietal lobe
Parieto-occipital sulcus
Occipital lobe
Medulla oblongata

Fig. 17.7: Developmental stages of cerebral cortex

Development of Spinal Nerve Roots

Motor nerve begins to appear during the 4th week of development, arising from nerve cells located in the basal lamina (ventral horn) of spinal cord. Dorsal nerve roots form the collection of fibres arising from the cells of the dorsal root ganglia (spinal ganglion). Central processes from these ganglia form bundles that grow into spinal cord opposite the dorsal horns. Almost immediately, spinal nerve divides into dorsal and ventral rami. Dorsal primary rami supply dorsal axial musculature and skin of back. Ventral primary rami supply limbs, ventral body wall and form major nerve plexuses, i.e. cervical, brachial and lumbosacral plexuses (Figs 17.8a and b).

The peripheral processes of the dorsal nerve root ganglia grow upwards to form sensory component of the spinal nerve. Axons of neurons in the dorsal grey column enter marginal layer to form ascending tracts of the spinal cord, and the axons of cells of neurons developing in various parts of brain enter the marginal layer to form descending tracts.

As the mantle layer forms the dorsal and ventral columns, the white matter becomes subdivided into dorsal, ventral and lateral white columns.

Positional Changes of Spinal Cord

During the third month of intrauterine life, the spinal cord extends the entire length of embryo. Due to rapid growth of dura mater and vertebral column as relative to the neural tube, the terminal end of spinal cord is located, at birth, at the level of 3rd lumbar vertebra. This process of recession continues after birth, as a result of which, in the adult, spinal cord usually ends at the upper border of 2nd lumbar or at lower border of 1st lumbar vertebra.

Below this level, a thread-like extension of pia mater forms filum terminale and is attached to the periosteum of coccyx. Nerve fibres below the level of cord are called cauda equina (horse's tail).

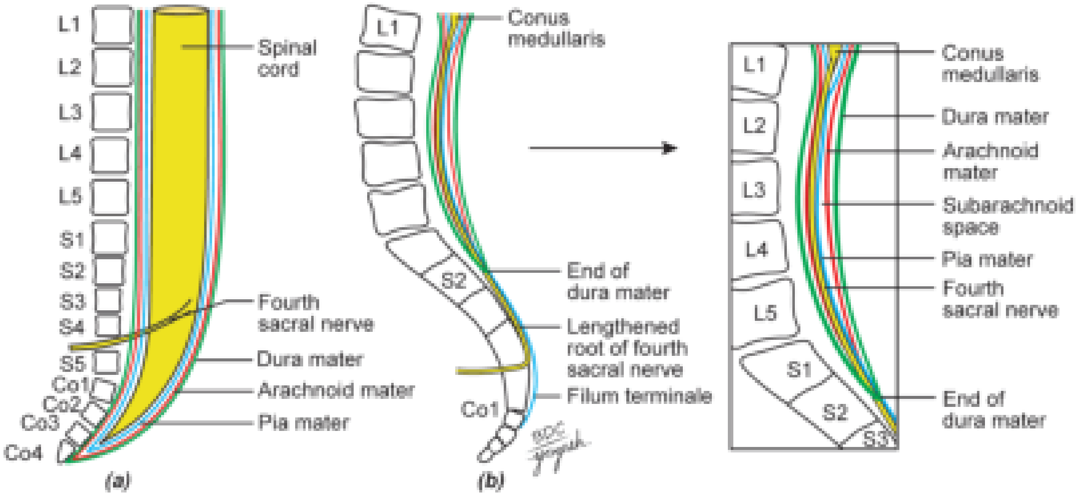
Because of this recession of spinal cord, the intervertebral foramen no longer lie at the level at which corresponding nerves emerge from the spinal cord. The nerves run obliquely to reach their respective foramen. The obliquity is least in lower cervical region, gradually increases and is more in lumbar, sacral and coccygeal regions.

One advantage of this recession of spinal cord is when cerebrospinal fluid is tapped for diagnostic purposes. During a lumbar puncture, the needle is inserted at the lower lumbar level, avoiding the lower end of the cord.

DEVELOPMENT OF BRAINSTEM

Development of Medulla Oblongata

Medulla oblongata develops from caudal myelencephalic part of the rhombencephalic vesicle. Neuroblasts from the alar plate of the neural tube at this level will develop into the sensory nuclei of the medulla. The neuroblasts of basal plate will give rise to the motor nuclei.


L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
Co1
Co2
Co3
Co4
Spinal cord
Fourth sacral nerve
Dura mater
Arachnoid mater
Pia mater
(a)
L1
S2
Co1
Conus medullaris
End of dura mater
Lengthened root of fourth sacral nerve
Filum terminale
(b)
L1
L2
L3
L4
L5
S1
S2
S3
Conus medullaris
Dura mater
Arachnoid mater
Subarachnoid space
Pia mater
Fourth sacral nerve
End of dura mater

Figs 17.8a and b: Ascent of the spinal cord: (a) In intrauterine life and (b) in adult; and inset

Development of Pons

Pons develops from cranial metencephalic part of rhombencephalic vesicle. Cells of alar lamina migrate to form the pontine nuclei, cochlear and vestibular nuclei, and trigeminal sensory nucleus. Basal plate neuroblasts give rise to abducens nucleus, facial nucleus, motor nucleus of trigeminal and superior salivatory nucleus.

Development of Midbrain

Midbrain develops from middle vesicle or the mesencephalon. Alar lamina cells multiply and fuse to form 4 colliculi. These cells also migrate ventrally to form red nucleus and substantia nigra. The basal lamina forms the crus cerebri.

DEVELOPMENT OF CEREBELLUM

Cerebellum develops from the neurons of alar lamina of metencephalic part of the rhombencephalic vesicle. These neurons migrate dorsally and form the rhombic lip which forms the cerebellum. The earliest part to develop is the archicerebellum. In its centre, the paleocerebellum develops, splitting the archicerebellar parts into two parts—the lingula and flocculonodular lobe. Lastly, the paleocerebellar part is also split by the development of neocerebellum in its centre into two parts—the anterior lobe except lingula and pyramid with uvula.

Competency:

AN64.3 Describe various types of open neural tube defects with its embryological basis.

CLINICAL NEUROANATOMY

Down syndrome: Down syndrome (DS) is a set of physical and mental traits caused by a gene problem which happens before birth. The affected persons may have some degree of intellectual disability. Normally, a person has 46 chromosomes. But, a person with DS has 47 chromosomes having extra or abnormal chromosomes changes the way the brain and body develops.

Clinical features: Flat face, small ears, slanting eyes, small mouth, short neck, short arms and legs, low muscles tone, loose joints, and below average intelligence.

Cerebral palsy: It is a neurological disorder by a nonprogressive brain injury or malformation that occurs while the child's brain is undergoing development. The brain damage is caused by brain injury or abnormal development of the brain that occurs—before birth, during birth or immediately after birth. Cerebral palsy may be of different types.

Clinical features: Affected parts are body movements, muscles control, muscle coordination and muscle tone.

Craniosynostosis (*cranio*, cranium; *syn*, together; *ostosis,* relating to bone): It is a condition in which one or more of the fibrous sutures in an infant (very young) skull prematurely fuses by turning into bone (ossification).

Attention deficit hyperactive disorder (ADHD): A disorder that includes difficulty staying focused and paying attention, difficulty controlling behaviour and hyperactivity. ADHD is not considered to be a learning disability.

Autism: It is a neurodevelopmental disorder characterised by impaired social interaction, impaired verbal and non-verbal communication, and restricted and repetitive behaviour. Autism affects information processing in the brain by altering how nerve cells and their synapses connect and organise. How this occurs is not well understood.

Symptoms: Impaired social interaction, impaired verbal and non-verbal communication, restricted and repetitive behaviour.

Causes: Genetic and environmental factors.

Convulsion: A sudden, violent, irregular movement of the body, caused by involuntary contraction of muscles and associated especially with brain disorders such as epilepsy, the presence of certain toxins or other agents in the blood or fever in children.

Epilepsy: It is a chronic disorder, the hallmark of which is recurrent, unprovoked seizures or convulsions. A person is diagnosed with epilepsy, if they have two unprovoked seizures (or one unprovoked seizure with the likelihood of more) that were not caused by some known and reversible medical condition like alcohol withdrawal or extremely low blood sugar.

Spinal stenosis: It is narrowing of the spinal canal. The narrowing of the spinal canal limits the amount of space for the spinal cord and nerves. Pressure on the spinal cord and nerves due to limited space can cause symptoms such as pain, numbness, and tingling.

Spina bifida: It is a birth defect where there is incomplete closing of the backbone and membranes around the spinal cord. There are three main types: Spina bifida occulta, meningocele, and myelomeningocele. The most common location is the lower back, but in rare cases it may be the middle back or neck. Occulta has no or only mild signs. Signs of occulta may include a hairy patch, simple, dark spot, or swelling on the back at the site of the gap in the spine. The meningocele typically causes mild problems with a sac of fluid present at the gap in the spine.

Guillain-Barre syndrome: It is a rare but serious autoimmune disorder in which the immune system attacks healthy nerve cells in one's peripheral nervous system. This leads to weakness, numbness and tingling. It can eventually cause paralysis. The cause of this condition is unknown, but it is typically triggered by an infectious illness, such as the stomach flu or a lung infection.

The symptoms of Guillain-Barre include:

- Tingling or prickly sensations in fingers and toes
- Muscle weakness in legs that travels to upper body and gets worse over time
- Difficulty in walking steadily
- Difficulty moving eyes or face, chewing or swallowing

- Severe lower back pain
- Loss of bladder control
- Fast heart rate
- Difficulty breathing
- Paralysis

Stroke: It occurs when the supply of blood to the brain is either interrupted or reduced. When this happens, the brain does not get enough oxygen or nutrients, and brain cells start to die. Ischemic strokes are caused by arteries being blocked or narrowed, and so treatment focuses on restoring an adequate flow of blood to the brain.

Hemorrhagic strokes are caused by blood leaking into the brain, so treatment focuses on controlling the bleeding and reducing the pressure on the brain.

Chiari malformation: It is a condition in which brain tissue extends into the spinal canal. It occurs when part of the skull is abnormally small or misshapen, pressing on the brain and forcing it downward. Chiari malformation is categorised into three types, depending on the anatomy of the brain tissue that is displayed into the spinal canal. Chiari malformation type I develops as the skull and brain are growing. As a result, signs and symptoms may not occur until late childhood or adulthood. The paediatric forms, Chiari malformation type II and type III, are present at birth (congenital).

Spina bifida: In spina bifida, the vertebral arches and spines of a few vertebrae do not develop. Underneath the bony defect, the spinal cord and meninges may also be affected due to failure of mesenchyme forming the vertebral arches. Types of spina bifida (Fig. 17.9) are:

a. *Spina bifida occulta:* The defect is only bony.
b. *Meningocele:* Meninges protrude through the bony defect.
c. *Meningomyelocele:* Meninges and spinal cord protrude through the bony defect.
d. *Rachischisis:* The spinal cord and meninges do not develop.

DEVELOPMENT OF AUTONOMIC NERVOUS SYSTEM

Sympathetic Portion

Sympathetic pathways consist of two neurons, i.e. preganglionic and postganglionic. The preganglionic neurons develop in the mantle layer of thoracolumbar segments of spinal cord—T1–L2 segments. These neurons are located in the general visceral efferent column or intermediate zone and form the lateral horn of the spinal cord. The axons arising from these neurons are myelinated and pass into ventral nerve roots to enter spinal nerves. After a short course, they leave the spinal nerve and pass towards postganglionic neurons.

Postganglionic neurons develop in the 5th week of intrauterine life; cells originating in the neural crest of the thoracic region migrate on each side of spinal cord towards the region immediately behind the dorsal aorta. Here they form a bilateral chain of segmentally arranged sympathetic ganglia interconnected by longitudinal nerve fibres. Together they form the sympathetic chains located on each side of vertebral column. From positions in the thorax, neuroblasts migrate towards cervical and lumbosacral regions, thus extending sympathetic chain to their full length. The arrangement is obscured in the cervical region by fusion of the ganglia.

Some neuroblasts migrate in front of aorta to form preaortic ganglia like coeliac, and mesenteric ganglia.

The nerve fibres originating in the visceroefferent column (lateral horn) of thoracolumbar segments of spinal cord synapse with neurons of sympathetic ganglion at the same level in sympathetic chain or pass through the chain to preaortic or collateral ganglion. The preganglionic fibres have myelin sheath and stimulate sympathetic ganglion cells. Passing from spinal nerves to sympathetic ganglion, they form the white ramus communicans. Since the visceroefferent column extends from T1–L2 segments of spinal cord, white rami communicantes are found only at T1–L2 levels.

Axons of sympathetic ganglion cells are called postganglionic fibres and have no myelin sheath. They pass either to other levels of sympathetic chain or extend to heart, lungs and intestinal tract.

Other fibres known as grey rami communicantes pass from sympathetic chain to spinal nerves and from there to peripheral blood vessels, arrector pilorum muscles and sweat glands. Grey rami communicantes are found at all levels of spinal cord.

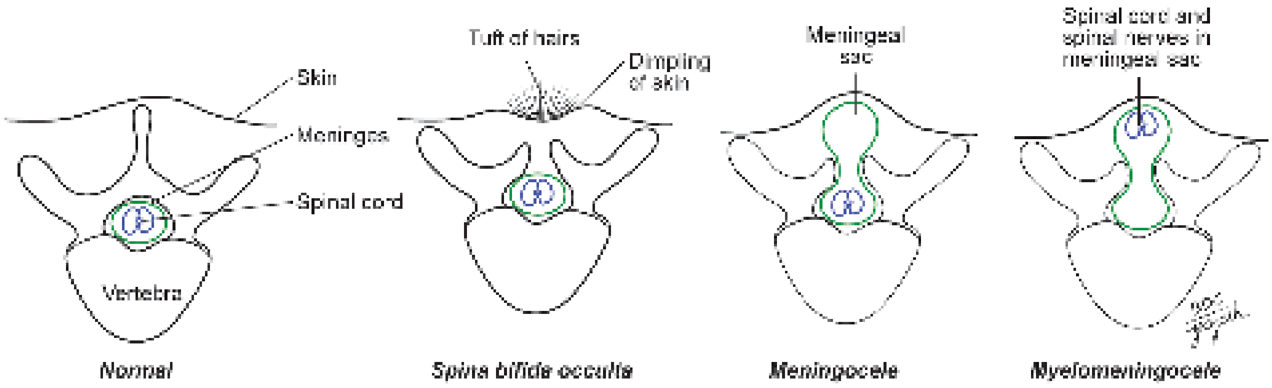


Fig. 17.9: Types of spina bifida

Parasympathetic Portion

Preganglionic neurons are formed in the brainstem and sacral region of spinal cord.

These neurons in the brainstem are located in general visceral efferent column. These give rise to Edinger-Westphal nucleus, lacrimatory, superior salivatory and inferior salivatory nuclei and dorsal nucleus of vagus. Their axons constitute the cranial parasympathetic outflow.

The sacral preganglionic neurons are derived from the mantle layer of sacral part of the spinal cord, their axons constitute the sacral parasympathetic outflow.

Postganglionic neurons of cranial region are derived from neural crest cells. These neurons form ciliary, otic, sphenopalatine and submandibular ganglia and also the ganglia associated with various viscera supplied by vagus nerve. Postganglionic axons arise from these neurons in the ganglia and supply constrictor pupillae, lacrimal gland, salivary gland and various viscera.

According to some investigators, postganglionic neurons of the brain arise from same region as the preganglionic neurons and migrate along the path followed by postganglionic fibres.

In the sacral region, the postganglionic neurons migrating from the sacral part of the spinal cord supply pelvic viscera and distal one-third of transverse colon, descending colon, pelvic colon, and rectum.

BDC's Anatomy e-book

1. Molecular regulation of development of spinal cord and brain
2. Viva voce questions

Appendix

Ventricles, Cranial Nerves and Arteries

SUMMARY OF THE VENTRICLES OF THE BRAIN

LATERAL VENTRICLE

The lateral ventricle comprises a central body and three horns—anterior, posterior and inferior. Their walls are enumerated.

Body or Central Part

Roof: Trunk of corpus callosum.

Floor: Superior surface of thalamus, thalamostriate vein, stria terminalis, body of caudate nucleus.

Medial: Septum pellucidum, body of fornix.

Anterior Horn

Roof: Anterior part of trunk of corpus callosum.

Anterior: Genu and rostrum of corpus callosum.

Floor: Head of caudate nucleus.

Medial wall: Septum pellucidum and column of fornix.

Posterior Horn

Roof and lateral wall: Tapetum of corpus callosum.

Medial wall: Bulb of posterior horn above and calcar avis below.

Inferior Horn

Roof and lateral wall: Tapetum, tail of caudate nucleus, stria terminalis and amygdaloid nucleus.

Floor: Pes hippocampus, hippocampus, alveus, fimbria, dentate gyrus and collateral eminence.

THIRD VENTRICLE

The third ventricle lies between the two thalami. The components of its boundaries and recesses are enumerated:

Anterior wall: Lamina terminalis, anterior commissure, anterior column of fornix (*see* Fig. 9.1).

Posterior wall: Pineal body and cerebral aqueduct.

Floor: Optic chiasma, tubercinerium, infundibulum, mammillary body, posterior perforated substance and tegmentum of midbrain.

Roof: Ependyma, tela choroidea.

Lateral wall: Medial surface of thalamus, medial aspect of hypothalamus, epithalamus and interventricular foramen.

Recesses: Infundibular recess, optic recess, pineal recess, suprapineal recess (*see* Fig. 9.1).

FOURTH VENTRICLE

The cavity of fourth ventricle is situated dorsal to pons and upper part of medulla oblongata and ventral to the cerebellum. Its boundaries, recesses, apertures and continuations are mentioned here:

Lateral boundaries: Gracile tubercle, cuneate tubercle inferior cerebellar peduncles and superior cerebellar peduncles.

Upper part: Facial colliculus on the dorsal surface of pons.

Intermediate part: Vestibular nuclei, medullary striae.

Lower part: Upper part of medulla oblongata containing hypoglossal and vagal triangles.

Roof: Superior medullary velum, thin sheet of pia mater and ependyma with median aperture, inferior medullary velum (*see* Fig. 7.2).

Recesses in roof: One median dorsal, two lateral dorsal and two lateral.

Apertures: One median—foramen of Magendie, two lateral—foramina of Luschka (left and right).

Continuity: Above with cerebral aqueduct. Below with central canal of spinal cord.

NUCLEAR COMPONENTS OF CRANIAL NERVES

The cranial nerve nuclei, their locations and functions are listed in Table A.1.

ARTERIES OF BRAIN

Vertebral Artery

Vertebral artery, a branch of 1st part of subclavian artery, is divided into four parts:

1. *First part:* Lies deep in the neck in the vertebral triangle; gives no branches.

TABLE A.1: Cranial nerve nuclei

Component	*Nucleus*	*Location*	*Function*
General somatic efferent (GSE) (supply skeletal muscle of somatic origin)	Oculomotor nucleus	Midbrain at the level of the superior colliculus	Supply 4½ extrinsic muscles of the eyeball except the lateral rectus and the superior oblique
	Trochlear nucleus	Midbrain at the level of the inferior colliculus	Superior oblique muscle through the trochlear nerve
	Abducent nucleus	Lower part of the pons	Lateral rectus muscle through the abducent nerve
	Hypoglossal nucleus	Extends into both the open and closed parts of the medulla	Seven out of eight muscles of the tongue through the hypoglossal nerve
Special visceral efferent (SVE) (supply striated muscle derived from the branchial arches)	Motor nucleus of the trigeminal nerve	Upper part of the pons	Muscles of mastication through the mandibular nerve
	Nucleus of the facial nerve	Lower part of the pons	Various muscles innervated by the facial nerve
	Nucleus ambiguus	In both the open and closed parts of the medulla	Stylopharyngeus muscle through the glossopharyngeal nerve; and Muscles of the soft palate, the pharynx and the larynx through the vagus nerve and the cranial part of the accessory nerve
General visceral efferent (give origin to preganglionic neurons that relay in a peripheral autonomic ganglion. Postganglionic fibres arising in the ganglion supply smooth muscles or glands)	Edinger-Westphal nucleus	In the midbrain in close relation to the oculomotor nucleus	Through the oculomotor nerve to the ciliary ganglion to supply the sphincter pupillae and the ciliaris muscles
	Lacrimatory nucleus	In the lower pons	Fibres that pass through the facial nerve and its branch, the greater petrosal nerve to relay in the pterygopalatine ganglion and supply the lacrimal, nasal, palatal and pharyngeal glands
	Superior salivatory nucleus	In the lower part of the pons	Through the facial nerve and its chorda tympani branch to the submandibular ganglion for supply of the submandibular, sublingual salivary glands and glands in the oral cavity
	Inferior salivatory nucleus	In the lower part of the pons just below the superior nucleus	Through the glossopharyngeal nerve to the otic ganglion for supply of the parotid gland
	Dorsal nucleus of the vagus	Open and closed parts of the medulla	Fibres that pass through the vagus nerve to be distributed to thoracic and abdominal viscera (the ganglia concerned are present in the walls of the viscera supplied)
General visceral afferent (GVA) and special visceral afferent (SVA)	Nucleus of solitary tract	In the medulla and extends into both its closed and open parts	Its lower part receives general visceral sensations as follows: a. Through the glossopharyngeal nerve from the tonsil, pharynx, posterior part of the tongue, carotid body and carotid sinus b. Through the vagus nerve from the pharynx, larynx, trachea, oesophagus and other thoracic and abdominal viscera Its upper part also receives sensations of taste (special visceral afferent) as follows: a. From the anterior two-thirds of the tongue, and the palate except circumvallate papillae through the facial (VII) nerve in its superior part b. From the posterior one-third of the tongue through the glossopharyngeal nerve (IX) including the circumvallate papillae in its middle part c. From the posteriormost part of the tongue and from the epiglottis through the vagus (X) nerve in its inferior part

(Contd.)

TABLE A.1: Cranial nerve nuclei *(Contd.)*

Component	*Nucleus*	*Location*	*Function*
General somatic afferent (GSA)	Main or superior sensory nucleus of the trigeminal nerve	Upper part of the pons	Fine and discriminatory touch, pressure sensation from head and neck
	Spinal nucleus of the trigeminal nerve	Medulla	Pain, temperature from forehead, cheek, from around mouth
	Mesencephalic nucleus of the trigeminal nerve	Midbrain	Exteroceptive sensations (touch, pain, temperature) from the skin of the face, through the trigeminal nerve; and from a part of the skin of the auricle through the vagus (auricular branch) and through the facial nerve. Proprioceptive sensations from muscles of mastication reach the mesencephalic nucleus through the trigeminal nerve. The nucleus is also believed to receive proprioceptive fibres from the ocular, facial and lingual muscles, teeth and temporomandibular joint
Special somatic afferent (SSA)	Cochlear nuclei (dorsal and ventral)	Pons	Impulses of hearing through the cochlear nerve
	Vestibular nuclei (superior, spinal, medial and lateral)	Pons	Receive fibres from the semicircular canals, the utricle and the saccule through the vestibular nerves

2. *Second part:* Passes in the foramen transversaria of C6–C1 vertebrae; gives spinal branches for supply of meninges and spinal cord.
3. *Third part:* Lies in the suboccipital triangle, on the posterior arch of atlas vertebra and gives branches to muscles of suboccipital triangle.
4. *Fourth part:* Enters the cranial cavity through foramen magnum. Joins with the same artery of opposite side to form basilar artery at the lower border of pons.
   The fourth part gives:
   a. Meningeal branches
   b. Posterior spinal artery
   c. Anterior spinal artery
   d. Posterior inferior cerebellar artery
   e. Medullary branches.

Basilar Artery

Right and left vertebral arteries unite at the lower border of the pons to form a median basilar artery, which gives following branches:

1. Anterior inferior cerebellar
2. Pontine branches
3. Labyrinthine branches
4. Superior cerebellar
5. Posterior cerebral.

Internal Carotid Artery (ICA)

1. Cervical part gives no branches.
2. Petrous part gives: (i) caroticotympanic for the middle ear, and (ii) pterygoid branches.
3. Cavernous part gives branches to: (i) trigeminal ganglion, and (ii) superior and inferior hypophyseal branches.
4. Cerebral part gives following branches:
   a. Ophthalmic artery which supplies outer layers of eyeball and retina through central artery of retina which is an end artery
   b. Anterior cerebral artery
   c. Middle cerebral artery continuation of ICA
   d. Posterior communicating artery
   e. Anterior choroidal artery.

Circle of Willis

Circle of Willis is formed by union of (i) anterior cerebral, (ii) terminal part of internal carotid, (iii) posterior communicating branch of internal carotid, (iv) joining the posterior cerebral branch of vertebral artery on each side. The two anterior cerebral arteries are joined by anterior communicating artery.

Branches of Circle of Willis

Central branches: These are long, thin, numerus end arteries which supply deeper structures like internal capsule and basal ganglia.

Choroidal branches: Choroidal branches of internal carotid and posterior cerebral arteries supply choroid plexuses of the ventricles.

Cortical branches: These are:

a. *Anterior cerebral:* Chief artery on the medial surface of cerebral hemisphere till parieto-occipital sulcus. It also supplies 1 cm wide area on the superolateral surface, along the superomedial border. The area includes motor and sensory areas of lower limb and perineum.
b. *Middle cerebral:* Main artery of the superolateral surface supplying major parts of motor and sensory areas. It also supplies motor speech, auditory and vestibular areas.
c. *Posterior cerebral:* Chief artery of the tentorial surface and occipital lobe. This is the artery of visual cortex.

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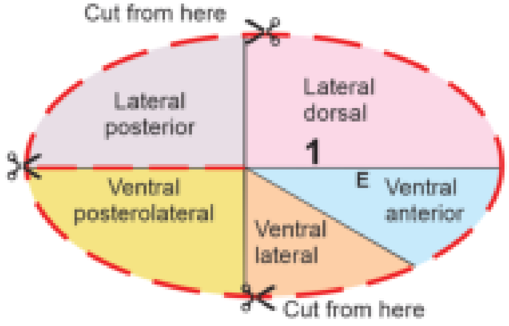
RIGHT THALAMUS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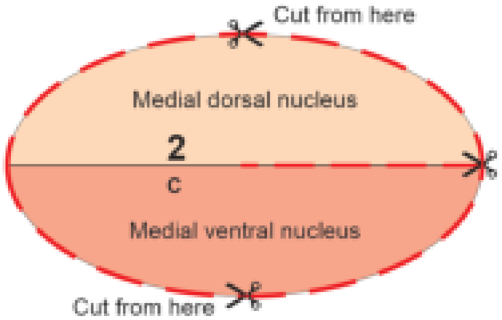
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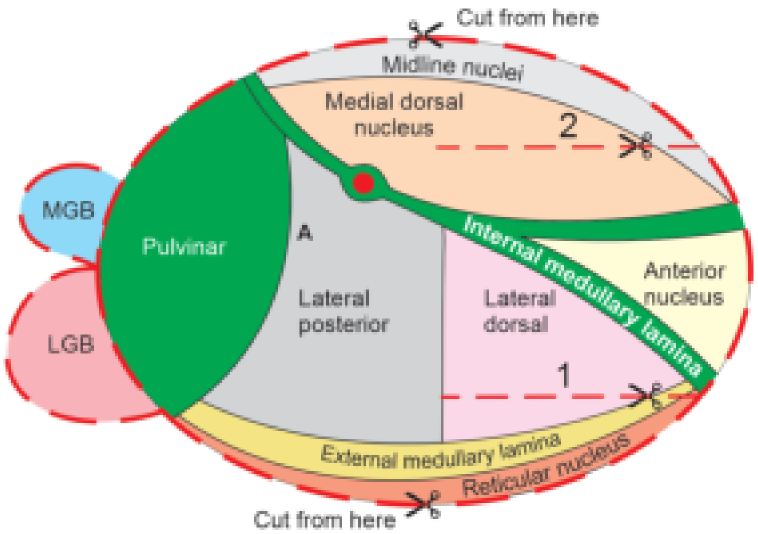
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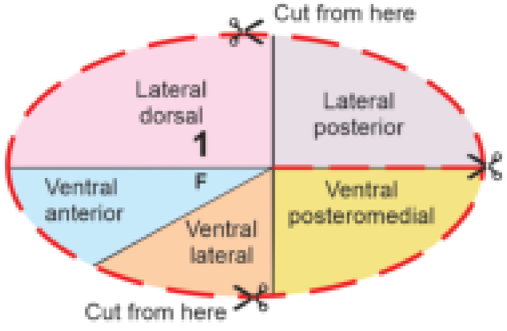
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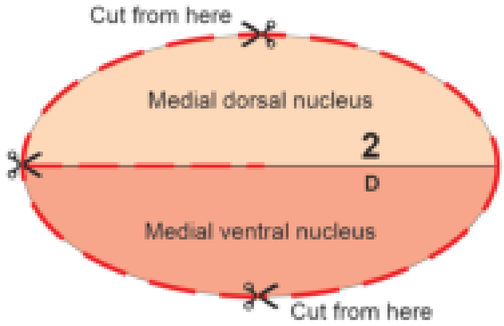
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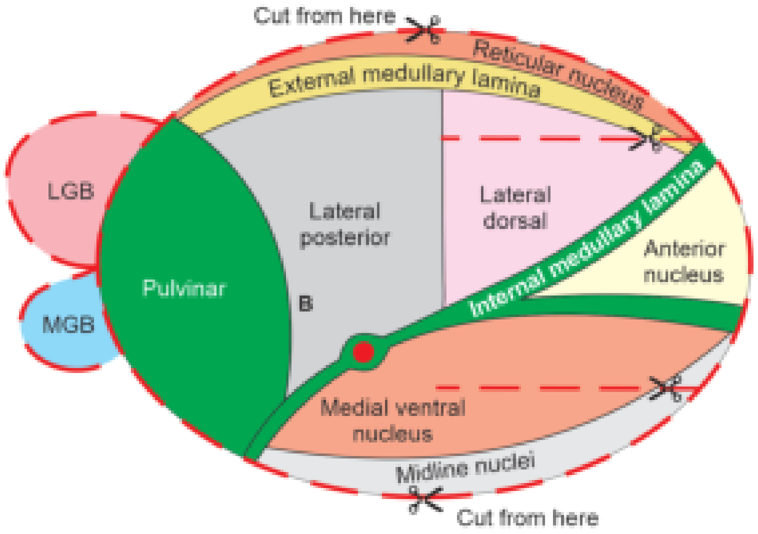
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Lateral posterior
Lateral dorsal
Internal medullary lamina
Anterior nucleus
Pulvinar
B
MGB
Medial ventral nucleus
Midline nuclei
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- Cut figures A, B, C, D, E and F
- Paste B, D and F on the undersurface of A, C and E respectively
- Insert CD and EF in the appropriate cuts in the AB and match 1 with 1 and 2 with 2

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